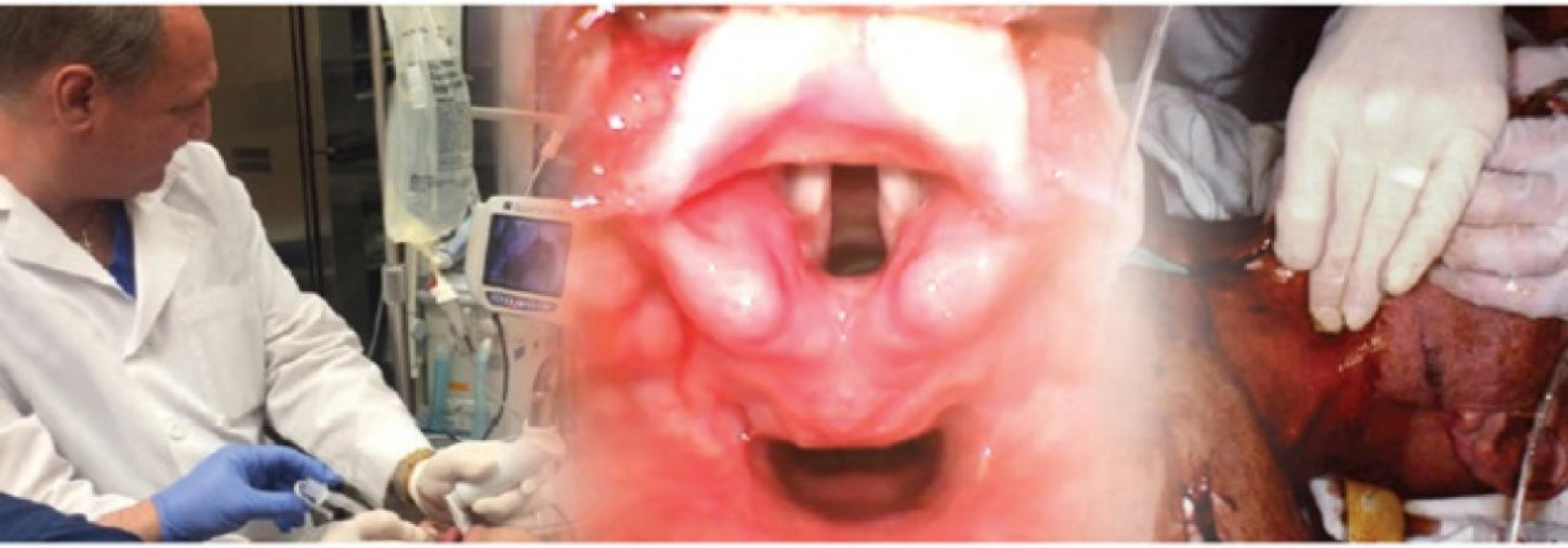
THE WALLS MANUAL OF

Emergency Airway Management

Sixth Edition



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the difficult airwaycourse*

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This book is dedicated to our friend and colleague Aaron E. Bair, MD (1966–2018), who passed away after an extended illness. Aaron was a master of emergency airway management, education, and research, and he combined his considerable skills with wisdom, enthusiasm, humor, and occasional snark. He was one of the earliest instructors in The Difficult Airway Course and dedicated much of his professional career to teaching airway management to the emergency medicine community. Some of us were fortunate enough to work directly with Aaron and we can still hear his voice in our head when we manage difficult airway cases. Aaron was perpetually curious—always looking to improve how we teach airway management and provide better, safer care to our patients. He was not only a valued colleague and mentor but also a close friend to many authors in this edition. He left us far too soon but continues to live on with each airway session we teach and in the vision of this book to deliver practical, evidence-based, and refined knowledge to its readers.

Preface

It is with pride and incredible enthusiasm that we present this sixth edition of *The Walls Manual of Emergency Airway Management*. As with previous editions, this book has been extensively reworked and updated with new content, chapters, and the latest in evidence-based approaches to airway management. It is presented in a practical, yet creative style by our highly talented authors and editors, who teach with us in The Difficult Airway Course: Emergency, The Difficult Airway Course: Anesthesia, The Difficult Airway Course: Critical Care, and The Difficult Airway Course: EMS. Each topic has undergone a thorough review incorporating the latest information from the available literature to ensure the content is relevant, modern, and on the forefront of clinical medicine.

Cardinal elements of airway management remain constant between editions, yet others evolve, often at a rapid pace, leading to changes in patient assessment, intubation techniques, and pharmacologic utilization. To this end, the sixth edition contains several fundamental changes. The seven Ps of rapid sequence intubation (RSI), a foundational approach to airway management, continues to evolve. Starting with the fifth edition, we removed *Pretreatment* as a discrete pharmacologic action. This was replaced by *Preintubation Optimization* and has now been rebadged as *Physiologic Optimization*, further emphasizing the importance of cardiopulmonary stabilization prior to induction and positive pressure ventilation to mitigate peri-intubation hypoxemia and circulatory collapse. An entirely new chapter entitled the Identification of the Physiologically Difficult Airway was created to provide a framework that highlights the metabolic, physiologic, and hemodynamic factors that make emergency airway management complex and, oftentimes, hazardous. A new mnemonic, “CRASH,” is introduced to help identify high-risk patient features that herald physiologic threats. This new content complements the

information found in the chapter on Intubating the Highly Infectious Patient to provide clinicians with a comprehensive approach aimed at maximizing safety when intubating a patient with severe physiologic derangement, a common scenario during emergency airway management. The airway algorithms have undergone a critical reappraisal. As a result, we present updated algorithmic approaches. The Difficult Airway Algorithm has been modified to incorporate abnormal physiology as a potential trigger to invoke awake intubation techniques and the Crash Airway Algorithm has been replaced by the Cardiac Arrest Airway Algorithm to clarify the approach to airway management based on the adequacy of circulation rather than the perceived urgency for airway intervention. We have reduced the number of intubation attempts needed to activate the Failed Airway Algorithm from three to two in order to highlight the negative impact of multi-attempt intubations and the importance of moving to rescue reoxygenation plans earlier during emergency airway management.

The COVID-19 pandemic brought new challenges for frontline clinicians. Concerns about preoxygenation techniques, positive pressure ventilation, and rescue airway maneuvers conflicted, early on, with anxieties about both patient and provider safety. A new chapter on Intubating the Highly Infectious Patient addresses these topics head-on and outlines a comprehensive approach for safe and effective airway management. Lidocaine remains an outdated medication and, like in the fifth edition, is no longer part of emergency airway management. Fentanyl was historically recommended, as a sympatholytic agent, when intubation was required in the setting of a hypertensive emergency. Although fentanyl may be administered for patients with severe hypertensive crises as part of a holistic approach to blood pressure management, its benefit as a pharmacologic airway adjunct is unclear and is no longer a reflexive recommendation during emergency intubation. Etomidate has separated itself as the principal induction agent for RSI as its effectiveness is firmly established and recent data suggest it is the safest sedative in patients with hypotension. As with previous editions, we cover the latest in airway devices as more tools begin to incorporate high-definition video technology and advanced design elements to make them lighter, more ergonomic, and affordable.

This edition embodies what we believe to be the knowledge necessary for safe and effective emergency airway management. The principles, however, are applicable to a wide array of clinical settings including the intensive care unit, inpatient floors, and prehospital arena. The concepts we present in this sixth edition can be extrapolated to any area where urgent airway management might take place and is relevant for all clinicians, not just emergency medicine specialists. With new challenges, infectious threats, and an ever-evolving clinical landscape, the updated information in this book makes this latest edition a vital resource for every emergency airway manager and the most adaptable manual to date.

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Acknowledgments

Medicine is a journey, but one not traveled alone. Without the love and support of my parents, family, and my two incredible sons, Calvin and Caleb, I could not maintain the energy and commitment to academic emergency medicine—a field that is both demanding and amazingly rewarding at the same time. I remain thankful for the incredible mentorship I've received over the past two decades and continue to be inspired by our airway course attendees as well as our faculty, residents, and students at Mass General Brigham and Harvard Medical School.

Calvin A. Brown III, MD
Boston, Massachusetts

There are many people, including my family, colleagues, and patients, who have greatly enriched my personal life and academic career, and I am grateful to them all for their unwavering support. I would like to dedicate this manual to all the frontline healthcare providers, of every specialty and discipline, who manage the airways of critically ill and injured patients. It is through their tireless efforts, working in uncontrolled environments and under difficult circumstances, that numerous lives around the world are saved.

John C. Sakles, MD
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It is one of the great secrets of the Difficult Airway Course that the instructors get as much out of teaching as the participants every course, without exception. Beyond interacting with amazing clinicians from all over the country and world, some who work in conditions so austere as to boggle the mind, I learn a tremendous amount from my co-faculty. These

lessons extend from airway management to more general career and life wisdom. It is bar none, the highlight of my professional career. A special thanks to Dr. Bob Luten, who has a special place in my heart as one of the founding fathers of Pediatric Emergency Medicine and a true pioneer in pediatric airway management. Thank you as well to my family, wife Kellie, daughters Gracyn and Afton, for putting up with the frequent travel and know that time away from the family is never easy, but we feel we are truly making a difference.

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Experience becomes wisdom, wisdom becomes dogma, dogma becomes outdated … because of new experience. Thus goes the cycle of the art, and science, of medicine. What is great about airway management is how rapid that cycle is occurring with the increasing collaboration of all specialties responsible for airway management. The consequence, though, is there is never time to rest. I am grateful for all the experiences my patients have taught me, all the conversations over the years with experts, novices, trainees that stimulated new ideas, and for the mentorship from and friendship with the faculty of the Difficult Airway Course. Most of all, I would like to thank my family, Breann, Carter, and Aubrey, for constantly sacrificing because our work is never finished.

Jarrod M. Mosier, MD
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I am fortunate to have spent the better part of the last four decades caring for patients both inside and outside the hospital. I have worked alongside amazing clinicians at every level of training and continue to learn from each of them every day. The opportunity to pass along these experiences and incorporate evidence-based medicine as part of this textbook and the Difficult Airway Course is immensely rewarding and very humbling. The international faculty of the Difficult Airway Course: EMS are an amazing group that makes an incredible difference in the outcomes of countless patients that we will probably never know about. I would particularly like to appreciate Terry Steele and Mike Steuerwald who have helped make the

Difficult Airway Course: EMS what it is today. I cannot express enough gratitude to all the authors who have given their valuable time to contribute to this textbook. The vigorous debates with the other amazing editors over concepts have renewed my faith in healthy disagreement and compromise. Behind the scenes it has been my family and all our animals that have kept me healthy and sane—or at least as healthy and sane as a lifelong EMS provider and career emergency physician can really be.

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Contents

Preface
Acknowledgments
Contributors

SECTION I: Principles of Airway Management

1. **The Decision to Intubate**
   Calvin A. Brown III
2 **Identification of the Anatomically Difficult Airway**
   Calvin A. Brown III
3. **The Physiologically Difficult Airway**
   Jarrod M. Mosier • Bhupinder Natt
4. **Identification of the Failed Airway**
   Calvin A. Brown III
5. **The Emergency Airway Algorithms**
   Calvin A. Brown III
6. **Human Factors During Emergency Airway Management**
   Peter G. Brindley • Jocelyn M. Slemko
7. **Applied Functional Anatomy of the Airway**
   Michael F. Murphy

SECTION II: Oxygenation and Ventilation

8. **Principles of Peri-intubation Oxygenation**
   Robert F. Reardon • Brian E. Driver
9. **Non-Invasive Positive Pressure Ventilation and High-Flow Nasal Oxygen**
   Alan C. Heffner
10. **Mechanical Ventilation**
    Alan C. Heffner
11. **Oxygen and Carbon Dioxide Monitoring**
    Robert F. Reardon • Brian E. Driver

SECTION III: Basic Airway Management

12. Bag-Mask Ventilation
Robert F. Reardon • Steven C. Carleton

13. Extraglottic Devices
Erik G. Laurin • Leslie V. Simon • Darren A. Braude

14. Managing the Patient With an Extraglottic Device in Place
Darren A. Braude • Eli Torgeson • Michael T. Steuerwald

SECTION IV: Tracheal Intubation

15. Direct Laryngoscopy
Robert F. Reardon • Steven C. Carleton • Leslie V. Simon

16. Video Laryngoscopy
Brian E. Driver • John C. Sakles

17. Flexible Endoscopic Intubation
Alan C. Heffner • Calvin A. Brown III

18. Blind Intubation Techniques
Michael T. Steuerwald • Steven A. Godwin • Darren A. Braude

19. Emergency Surgical Airways
Michael A. Gibbs • David A. Caro • Robert F. Reardon

SECTION V: Pharmacology and Techniques of Airway Management

20. Rapid Sequence Intubation
Calvin A. Brown III • Ron M. Walls

21. Sedative-Induction Agents
David A. Caro • Katren R. Tyler

22. Neuromuscular Blocking Agents
David A. Caro • Erik G. Laurin

23. Optimizing First Attempt Intubation Success
Brian E. Driver • Robert F. Reardon

24. Anesthesia and Sedation for Awake Intubation
Steven C. Carleton • Alan C. Heffner

SECTION VI: Pediatric Airway Management

25. Differentiating Aspects of the Pediatric Airway
Robert C. Luten • Nathan W. Mick

26. Pediatric Airway Techniques

Robert C. Luten • Christyn F. Magill • Nathan W. Mick

27. The Difficult Pediatric Airway
Joshua Nagler • Robert C. Luten

28. Foreign Body in the Pediatric Airway
Robert C. Luten • Steven Bin • Christyn F. Magill

SECTION VII: EMS Airway Management

29. Introduction to EMS Airway Management
Michael J. Keller • Michael T. Steuerwald • Estêvão M. Lafuente

30. Techniques in Prehospital Airway Management
Chivas Guillote • Darren A. Braude

31. Difficult and Failed Airway Management in EMS
Michael T. Steuerwald • Fred Ellinger, Jr. • Joseph Loehner

32. Controversies in EMS Airway Management
Jamie Todd • Lauren M. Maloney • Darren A. Braude

SECTION VIII: Special Clinical Circumstances

33. The Unstable Patient: Cardiopulmonary Optimization for Emergency Airway Management
Jarrod M. Mosier • Alan C. Heffner • John C. Sakles

34. The Trauma Airway
Michael G. Gonzalez • Ali S. Raja

35. The Neurocritical Patient
Stephen Bush • Bret P. Nelson

36. Reactive Airways Disease
Heather Mahoney • Calvin A. Brown III

37. Distorted Airways and Acute Upper Airway Obstruction
Erik G. Laurin • Ali S. Raja

38. The Pregnant Patient
Megan Leigh Fix • Rebecca L. Kornas

39. Cardiovascular Emergencies
Rebecca L. Kornas • Stephen Bush

40. Intubating the Highly Infectious Patient
Katelin Morrissette • Jarrod M. Mosier

41. The Massively Soiled Airway
Darren A. Braude • Rudolph Princi • James C. DuCanto

42. The Geriatric Patient

Katren R. Tyler • Stephen Bush

43. The Morbidly Obese Patient
Megan Leigh Fix

44. Foreign Body in the Adult Airway
Tatsuya Norii • Heather Mahoney • Erik G. Laurin

45. Safe Extubation in the Emergency Airway Patient
Matteo Parotto

Index

Section I

Principles of Airway Management

1 The Decision to Intubate
2 Identification of the Anatomically Difficult Airway
3 The Physiologically Difficult Airway
4 Identification of the Failed Airway
5 The Emergency Airway Algorithms
6 Human Factors During Emergency Airway Management
7 Applied Functional Anatomy of the Airway

CHAPTER 1

The Decision to Intubate

Calvin A. Brown III

INTRODUCTION

Airway management is constantly evolving. The emergence of new technology, principally the various methods of video laryngoscopy, our understanding of contributors to intubation difficulty, and a renewed focus on effective preoxygenation and cardiovascular stability during airway management are changing our fundamental decision-making to maximize patient safety and outcome. What has not changed, however, is the critical importance of the determination of whether a patient requires intubation and, if so, how urgently. The decision to intubate is the first step in emergency airway management and sets in motion a complex series of actions required of the clinician, before performing the actual intubation:

- Rapidly assess the patient's need and indication for intubation and the urgency of the situation.
- Determine the best method of airway management based on assessment of the patient's predicted anatomic and physiologic difficulty.
- Decide which pharmacologic agents are indicated, in what order, and in what doses.
- Prepare reoxygenation and rescue intubation plans in the event that the primary method is unsuccessful. Know in advance how to recognize when the primary airway intervention has failed or will inevitably fail, and clearly lay out the sequence of alternative (rescue) technique(s).

Clinicians responsible for emergency airway management must be proficient with the techniques and medications used for rapid sequence intubation (RSI), the preferred method for most emergency intubations, as

well as alternative intubation strategies when induction and neuromuscular blockade are contraindicated. The entire repertoire of airway skills must be mastered, including bag-mask ventilation, video laryngoscopy, conventional (direct) laryngoscopy, flexible endoscopy, the use of extraglottic devices, adjunctive techniques such as use of an tracheal tube introducer (also known as the gum elastic bougie), and surgical airway techniques.

This chapter focuses on the decision to intubate. Subsequent chapters describe airway management decision-making, methods of ensuring oxygenation, techniques and devices for airway management, the pharmacology of RSI, and considerations for special clinical circumstances, including the prehospital environment and care of pediatric patients.

INDICATIONS FOR INTUBATION

The decision to intubate is based on three fundamental clinical assessments:

1. Is there a failure or impending failure of airway patency or protection?
2. Is there a failure or impending failure of ventilation or oxygenation?
3. Is the anticipated clinical course likely to require intubation?

The results of these three evaluations will lead to a correct decision to intubate or not to intubate in virtually all conceivable cases.

Is there a failure of airway patency or protection?

Without a patent airway and intact protective reflexes, adequate oxygenation and ventilation may be difficult or impossible and aspiration of gastric contents can occur. Both expose the patient to significant morbidity and mortality. The conscious, alert patient uses the musculature of the upper airway and various protective reflexes to maintain patency and to protect against aspiration of foreign substances, blood, gastric contents, or secretions. The patient’s ability to phonate with a clear, unobstructed voice is strong evidence of airway patency, protection, and cerebral perfusion. In the severely ill or injured patient, such airway maintenance and protection mechanisms are often attenuated or lost. If the spontaneously breathing patient is not able to maintain a patent airway, an artificial airway may be established by the insertion of an oropharyngeal or nasopharyngeal airway. Although such devices may restore patency, they do not provide any

protection against aspiration. Patients who are unable to maintain their own airway are also unable to protect it. Therefore, generally, any patient who requires the establishment of a patent airway or tolerates the presence of an artificial airway, also requires protection of that airway. The exception is when a patient has an immediately reversible cause of airway compromise (eg, opioid overdose) and reversal of the insult promptly restores the patient's ability to maintain an open, functioning airway. The need to protect the airway requires placement of a definitive airway (ie, a cuffed endotracheal tube), and devices that simply maintain, but do not protect, the airway, such as oropharyngeal or nasopharyngeal airways, are temporizing measures only. It was previously thought that the gag reflex was a reliable method of evaluating airway protective reflexes. In fact, this concept has never been subjected to adequate scientific scrutiny, and the absence of a gag reflex is neither sensitive nor specific as an indicator of loss of airway protective reflexes. The presence of a gag reflex has similarly not been demonstrated to ensure the presence of airway protection. In addition, testing the gag reflex in a supine, obtunded patient may result in vomiting and aspiration. Therefore, gag reflex testing has no clinical value, may be dangerous, and should not be used to assess the need for intubation.

Spontaneous or volitional swallowing is a better assessment of the patient's ability to protect the airway. Swallowing is a complex reflex that requires the patient to sense the presence of material in the posterior oropharynx and then execute a series of intricate and coordinated muscular actions to direct the secretions down past a covered airway into the esophagus. The finding of pooled secretions in the patient's posterior oropharynx indicates a potential failure of these protective mechanisms, and hence a failure of airway protection. A common clinical error is to assume that spontaneous breathing is proof that protective airway mechanisms are preserved. Although spontaneous ventilation may be adequate, the patient may be sufficiently obtunded to be at serious risk of aspiration.

Is there a failure of ventilation or oxygenation?

Stated simply, gas exchange is required for vital organ function. Even brief periods of hypoxia should be avoided, whenever possible. If the patient is unable to ventilate sufficiently, or if adequate oxygenation cannot be achieved despite the use of supplemental oxygen, then intubation is

indicated. In such cases, intubation is performed to facilitate ventilation and oxygenation rather than to establish or protect the airway. An example is the patient with status asthmaticus, for whom bronchospasm and fatigue lead to ventilatory failure and hypoxemia, heralding respiratory arrest and death. Airway intervention is indicated when it is determined that the patient will not respond sufficiently to treatment to reverse these cascading events. Similarly, although the patient with severe acute respiratory distress syndrome may be maintaining and protecting the airway, he or she may have progressive oxygenation failure and supervening fatigue that can be managed only with tracheal intubation and positive-pressure ventilation. Unless ventilatory or oxygenation failure is resulting from a rapidly reversible cause, such as opioid overdose, or a condition known to be successfully managed with noninvasive ventilation (eg, bi-level positive airway pressure [Bi-PAP] for acute pulmonary edema), intubation is required. Even then, the clinician must be vigilant and constantly reassess the patient's condition, and if there is not an early and clear trajectory of improvement, intubation is indicated.

What is the anticipated clinical course?

Most patients who require emergency intubation have one or more of the previously discussed indications: failure of airway patency airway protection, oxygenation, or ventilation. However, there is a large and important group for whom intubation is indicated, even though there are no immediate fundamental failures at the time of evaluation. These are the patients for whom intubation is likely or inevitable because their conditions are predicted to deteriorate from dynamic and progressive changes related to the presenting pathophysiology or because the work of breathing will become overwhelming in the face of catastrophic illness or injury. For example, consider the patient who presents with a stab wound to Zone II of the anterior neck and a visible hematoma. At presentation, the patient may have perfectly adequate airway maintenance and protection and be ventilating and oxygenating well. The hematoma, however, provides clear evidence of significant vascular injury. Ongoing bleeding may be clinically occult because the blood often tracks down the tissue planes of the neck rather than demonstrating visible external expansion of the hematoma. Furthermore, the anatomical distortion caused by the enlarging internal

hematoma may well thwart a variety of airway management techniques that would have been successful if undertaken earlier. The patient inexorably progresses from awake and alert with a patent airway to a state in which the airway becomes obstructed, often quite suddenly, and the anatomy is so distorted that airway management is difficult or impossible.

Similarly, an agitated polytrauma patient who presents with an open femur fracture, unstable pelvis, and hypotension may require intubation even though there may be no immediate threat to his airway. Intubation is indicated as part of the safe management of the constellation of injuries. The reason becomes clear when one examines the patient's anticipated clinical course. The hypotension mandates resuscitation and evaluation for the source of the blood loss, including abdominopelvic computed tomography (CT) scan. Unstable pelvic fractures with hypotension require immobilization and likely embolization of bleeding vessels. Open long bone fractures require aggressive pain control and inevitable operative intervention. If chest injury is suspected, chest tubes may be needed to treat hemopneumothorax or in preparation for positive-pressure ventilation during surgery. Combative behavior confounds efforts to maintain spine precautions and requires pharmacologic restraint and evaluation by head CT scan. Throughout all of this, the patient's shock state causes inadequate tissue perfusion and increasing metabolic debt. This debt significantly affects the muscles of respiration, and progressive respiratory fatigue and failure often supervene. With the patient's ultimate destination certain to be the operating room or the intensive care unit (ICU), and the need for complex and potentially painful procedures and diagnostic evaluations, which may require extended periods of time outside the resuscitation suite, this patient is best served by early intubation. In addition, intubation improves tissue oxygenation during shock and helps reduce the rising metabolic debt burden.

Sometimes, the anticipated clinical course may necessitate intubation because the patient will be exposed to a period of increased risk on account of patient transport, a medical procedure, or diagnostic imaging. For example, the patient with multiple injuries who appears relatively stable might be appropriately managed without intubation while geographically located in the emergency department (ED). However, if that same patient requires CT scans, angiography, or any other prolonged diagnostic

procedure, it may be more appropriate to intubate the patient before allowing him or her to leave the ED so that an airway crisis will not ensue in the radiology suite, where recognition may be delayed, and response may not be optimal. Similarly, if such a patient is to be transferred from one hospital to another, airway management may be indicated based on the increased risk to the patient during that transfer.

Not every trauma patient or every patient with a serious medical disorder requires intubation. However, in general, it is better to err on the side of performing an intubation that might not, in retrospect, have been required, than to delay intubation, thus exposing the patient to the risk of serious deterioration from aspiration or hypoxia.

APPROACH TO THE PATIENT

When evaluating a patient for emergency airway management, the first assessment should be of the patency and adequacy of the airway. In many cases, the adequacy of the airway is confirmed by having the patient speak. Ask questions such as “What is your name?” or “Do you know where you are?” The responses provide information about both the airway and the patient’s neurologic status. A normal voice (as opposed to a muffled or distorted voice), the ability to inhale and exhale in the modulated manner required for speech, and the ability to comprehend the question and follow instructions are strong evidence of adequate upper airway function. Although such an evaluation should not be taken as proof that the upper airway is definitively secure, it is strongly suggestive that the airway is adequate *at that moment*. More importantly, the inability of the patient to phonate properly; inability to sense and swallow secretions; or the presence of stridor, dyspnea, or altered mental status precluding responses to questioning should prompt a detailed assessment of the adequacy of airway protection and patency (see **Box 1.1**). After assessing verbal response to questions, conduct a more detailed examination of the mouth and oropharynx. Examine the mouth for bleeding, swelling of the tongue or uvula, abnormalities of the oropharynx (eg, peritonsillar abscess), or any other abnormalities that might interfere with the unimpeded passage of air through the mouth and oropharynx. Examine the mandible and central face for structural integrity. Examination of the anterior neck requires both

visual inspection for deformity, asymmetry, or abnormality and palpation of the anterior neck, including the larynx and trachea. During palpation, assess carefully for the presence of subcutaneous air. This is identified by a crackling feeling on compression of the subcutaneous tissues of the neck, much as if a sheet of wrinkled tissue paper were lying immediately beneath the skin. The presence of subcutaneous air indicates disruption of an air-filled passage, often the airway itself, especially in the setting of blunt or penetrating chest or neck trauma. Subcutaneous air in the neck also can be caused by pulmonary injury, esophageal rupture, or, rarely, gas-forming infection. Although these latter two conditions are not immediately threatening to the airway, patients may nevertheless rapidly deteriorate, requiring subsequent airway management. In the setting of blunt anterior neck trauma, assess the larynx for pain on motion. Move the larynx from side to side, assessing for "laryngeal crepitus," indicating normal contact of the airway with the air-filled upper esophagus. Absence of crepitus may be caused by edema between the larynx and the upper esophagus.

BOX 1.1 The CRASH Four Key Signs of Upper Airway Obstruction

- Muffled, hoarseness or "hot potato" voice (as though the patient is speaking with a mouthful of hot food)
- Inability to swallow secretions, because of either pain or obstruction
- Stridor
- Dyspnea

The first two signs do not necessarily herald imminent total upper airway obstruction; stridor, if new or progressive, usually does, and dyspnea is a compelling symptom.

After inspecting and palpating the upper airway, note the patient's respiratory pattern. The presence of inspiratory stridor, however slight, indicates significant upper airway obstruction. Lower airway obstruction, occurring beyond the level of the glottis, more often produces expiratory stridor. The volume and pitch of stridor are related to the velocity and turbulence of ventilatory airflow. Most often, stridor is audible without a stethoscope. Auscultation of the neck with a stethoscope can reveal subclinical stridor that may also indicate potential airway compromise. Stridor is a late sign, especially in adult patients, who have large-diameter

airways, and significant airway compromise may be present before stridor is evident. When evaluating the respiratory pattern, observe the chest through several respiratory cycles, looking for normal symmetrical, concordant chest movement. In cases where there is significant injury, paradoxical movement of a flail segment of the chest may be observed. If spinal cord injury has impaired intercostal muscle functioning, diaphragmatic breathing may be present. In this form of breathing, there is little movement of the chest wall, and inspiration is evidenced by an increase in abdominal volume caused by descent of the diaphragm. Auscultate the chest to assess the adequacy of air exchange. Decreased breath sounds may indicate pneumothorax, hemothorax, pleural effusion, emphysema, or other pulmonary pathology.

The assessment of ventilation and oxygenation is a clinical one. Arterial blood gas determination provides little additional information as to whether intubation is necessary and may be misleading. The patient's mentation, degree of fatigue, and severity of concomitant injuries or comorbid medical conditions is more important than isolated or even serial determinations of arterial oxygen or carbon dioxide (CO_2) tension. Oxygen saturation is monitored continuously by pulse oximetry, so arterial blood gases rarely are indicated for the purpose of determining arterial oxygen tension. In certain circumstances, oxygen saturation monitoring is unreliable because of poor peripheral perfusion, and arterial blood gases may then be required to assess oxygenation or to provide a correlation with pulse oximetry measurements. Waveform capnography may be used to assess changes in the patient's ability to ventilate adequately, and the measurement of arterial CO_2 tension contributes little additional useful information, although often a single arterial blood gas measurement is used to provide a correlation baseline with end-tidal CO_2 readings. A venous or arterial blood gas can provide a good general snapshot of the patient's acid-base status and baseline ventilation, but assessment of overall ventilation remains a clinical task, requiring evaluation of the patient's overall status and perceived trajectory. In patients with obstructive lung disease, such as asthma or chronic obstructive pulmonary disease (COPD), intubation may be required in the face of relatively low CO_2 tensions if the patient is becoming fatigued. Other times, high CO_2 tensions may be managed successfully with

noninvasive positive-pressure ventilation instead of intubation if the patient is showing clinical signs of improvement.

Finally, after assessment of the upper airway and the patient's ventilatory status, including pulse oximetry, capnography (if used), and mentation, consider the patient's anticipated clinical course. If the patient's condition is such that intubation is inevitable and a series of interventions are required, early intubation is preferable. Similarly, if the patient has a condition that is at risk of worsening over time, especially if it is likely to compromise the airway itself, early airway management is indicated. The same consideration applies to patients who require interfacility transfer by air or ground or a prolonged procedure in an area with diminished resuscitation capability. Intubation before transfer is preferable to a difficult, uncontrolled intubation in an austere environment after the condition has worsened. In all circumstances, the decision to intubate should be given precedence. If doubt exists as to whether the patient requires intubation, err on the side of intubating the patient. It is preferable to intubate the patient and ensure the integrity of the airway than to leave the patient without a secure airway and have a preventable crisis occur.

EVIDENCE

Are there reliable indicators of the need to intubate?

The clinician's determination regarding the need for intubation is based on the clinical scenario, pathophysiology, bedside airway assessment, and likelihood of deterioration. Some measurable data and patient characteristics can be helpful, whereas others are largely folklore. First, the gag reflex continues to be taught, in some settings, as a key determinant in assessing the adequacy of airway protection or the need for intubation, yet the literature does not support this claim. The patient's Glasgow Coma Scale is a better predictor of airway protection and his or her aspiration risk in overdose.[1] Inspiratory stridor, when seen in adults, is particularly ominous and often mandates intubation. Although there is no absolute cutoff for oxygen saturation or CO_2 that dictates intubation, a saturation that cannot be sustained above 80%, a RR >30 or a CO_2 >100 has strong associations with intubation. Moreover, many conditions can often be managed without definitive airway management even when the patient

seems, initially, to be in severe respiratory distress. COPD and acute pulmonary edema are uncommon causes of ED intubation and can typically be managed with medical therapy and noninvasive positive-pressure ventilation.[2]

Are there reliable predictors of the need for intubation in patients with known or suspected COVID-19?

Patients with COVID-19 can be managed with a variety of supportive strategies ranging from ambient pressure supplemental oxygen to high-flow nasal oxygen (HFNO) to tracheal intubation depending on the severity of hypoxemic respiratory failure. For patients treated with HFNO, a ROX index reliably predicts the likelihood of intubation. The ROX index is the ratio of Spo_2/Fio_2 to respiratory rate. A ROX index >4.88 indicates a low risk of intubation whereas an index <3.85 indicates a high rate of failure and eventual need for intubation.[3,4]

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CHAPTER 2

Identification of the Anatomically Difficult Airway

Calvin A. Brown III

INTRODUCTION

An anatomically difficult airway is one in which identifiable anatomic attributes predict technical difficulty with securing the airway. One can think about airway difficulty in two categories: an anatomically difficult airway and a physiologically difficult airway. The former presents anatomic barriers to successful airway management, whereas the latter requires the operator to optimize overall patient physiology in the context of critically low oxygen saturation, hemodynamic instability, or severe metabolic acidosis (discussed in Chapter 3). This chapter focuses on the anatomic issues related to airway management.

An anatomically difficult airway exists on a spectrum and is one in which a preintubation examination identifies physical attributes that are likely to make laryngoscopy, intubation, bag-mask ventilation (BMV), the use of an extraglottic device (EGD; eg, laryngeal mask airway [LMA] or King laryngeal tube [King-LT]), or surgical airway management more difficult than would be the case in an ordinary patient without those attributes. Some patients may have a single anatomic reason for airway difficulty, whereas others may have numerous difficult airway characteristics. Identification of an anatomically difficult airway is a key component of the approach to airway management for any patient and is a key branch point on the main airway algorithm (see Chapter 5). The key reason for this is that, depending on the degree of predicted difficulty, induction of anesthesia and use of neuromuscular blocking medications would be avoided in the face of severe anatomic limitation (ie, obstructing

oropharyngeal pathology) unless one has a measure of confidence that gas exchange can be maintained if laryngoscopy and intubation fail, or a forced-to-act scenario existed (see Chapter 5). Accordingly, if an anatomically difficult airway is identified, the difficult airway algorithm is used.

Airways that are difficult to manage because of anatomic challenges are common in emergency medicine practice. Difficult direct laryngoscopy (DL), defined as a grade III or grade IV laryngoscopic view, occurs in approximately 10% of all adult emergency intubations. The incidence is dramatically lower when a video laryngoscope is used (see Chapter 16). Recognizing the anatomically difficult airway in advance and executing an appropriate and thoughtful plan, guided by the difficult airway algorithm, will minimize the likelihood that airway management will fail.

THE DIFFICULT AIRWAY

According to the main emergency airway management algorithm, rapid sequence intubation (RSI) is the method of choice for any airway when significant airway management difficulty is not anticipated. This requires a reliable and reproducible method for identifying the difficult airway. This evaluation must be expeditious, easy to remember, and complete.
In clinical practice, the anatomically difficult airway has four dimensions:

1. Difficult laryngoscopy and intubation
2. Difficult BMV
3. Difficult EGD
4. Difficult cricothyrotomy

A distinct evaluation is required for difficult DL, difficult BMV, difficult EGD, and difficult surgical airway management, and each evaluation must be applied to each patient, when time allows, before airway management is undertaken (**Fig. 2.1**).

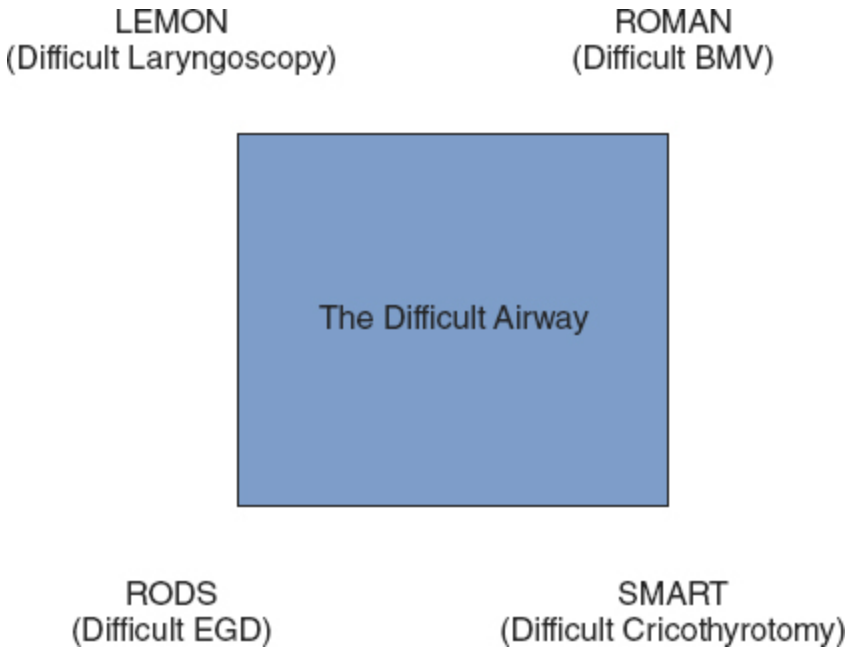

Figure 2.1: Difficult airway box. Note that the *four corners* represent the four dimensions of difficulty.

Difficult Laryngoscopy: LEMON

The concept of difficult laryngoscopy and intubation is inextricably linked to poor glottic view; the less adequate the glottic view, the more challenging the intubation. This concept, developed during an era when almost all intubations were done by DL, is still relevant even in the era of video laryngoscopy (VL). Nearly all research relating specific patient characteristics to difficult or impossible intubation is based on studies of DL. VL is much less affected than DL by the presence or number of difficult airway attributes; however, extreme abnormalities of some elements of LEMON will affect both DL and VL alike. Severely reduced mouth opening, for example, makes it impossible for any laryngoscope blade to be inserted. So, although abnormal LEMON findings will differentially impact DL more, we recommend performing a difficult laryngoscopy assessment, using the LEMON mnemonic, on all patients for whom intubation is planned, including for planned VL. When able to be inserted, it is rare for VL, particularly hyperangulated VL (HA-VL), to yield a Cormack and Lehane (C-L) grade III (or worse) glottic view. VL accomplishes this independently of the need to align the various airway axes, as must occur during DL (see Chapters 15 and 16). It follows that

evidence-based guidelines for prediction of difficult VL may be challenging, or even impossible, to create. A mnemonic for difficult VL, CRANE (see “Evidence” section), has been developed, based on limited evidence from the anesthesia literature, but its utility in emergency airway management is unclear. If orotracheal intubation is planned and the airway is not overwhelmingly soiled or obliterated by large obstructing airway pathology, then VL provides the best opportunity for intubation success despite the presence of other “CRANE” abnormalities. Providers should proceed with using VL unless patient characteristics are present that would make both VL and DL virtually impossible, in which case, another approach may be required (ie, nasotracheal flexible VL for advanced angioedema of the tongue).

C-L introduced the most widely used system of categorizing the degree of visualization of the larynx during DL, in which a complete laryngoscopic view is designated grade 1 and the worst possible view, grade 4 (**Fig. 2.2**). C-L grade 3 view (only the epiglottis is visible) and grade 4 view (no glottic structures are visible) are highly correlated with difficult or failed intubation. C-L grade 1 (visualization of virtually the entire glottic aperture) and grade 2 (visualization of the posterior portion of the cords or the arytenoids) are not typically associated with difficult intubation. The C-L grading system does not differentiate precisely the degree to which the laryngeal aperture is visible during laryngoscopy: A grade 2 view may reveal little of the vocal cords, or none if only the arytenoids are visible. This led to adoption of a grade 2a/2b system, wherein a 2a shows any portion of the cords and a 2b shows only the arytenoids. Grade 2a airways perform comparably to those scored as grade 1, whereas grade 2b airways behave more like grade 3 airways. When DL is used, grade 2b accounts for only about 20% of grade 2 views. However, when a grade 2b view occurs, two-thirds of patients are difficult to intubate, whereas only about 4% of patients with grade 2a views are characterized as difficult intubations. A grade 1 view reveals virtually the entire glottis and is associated with nearly universal intubation success.

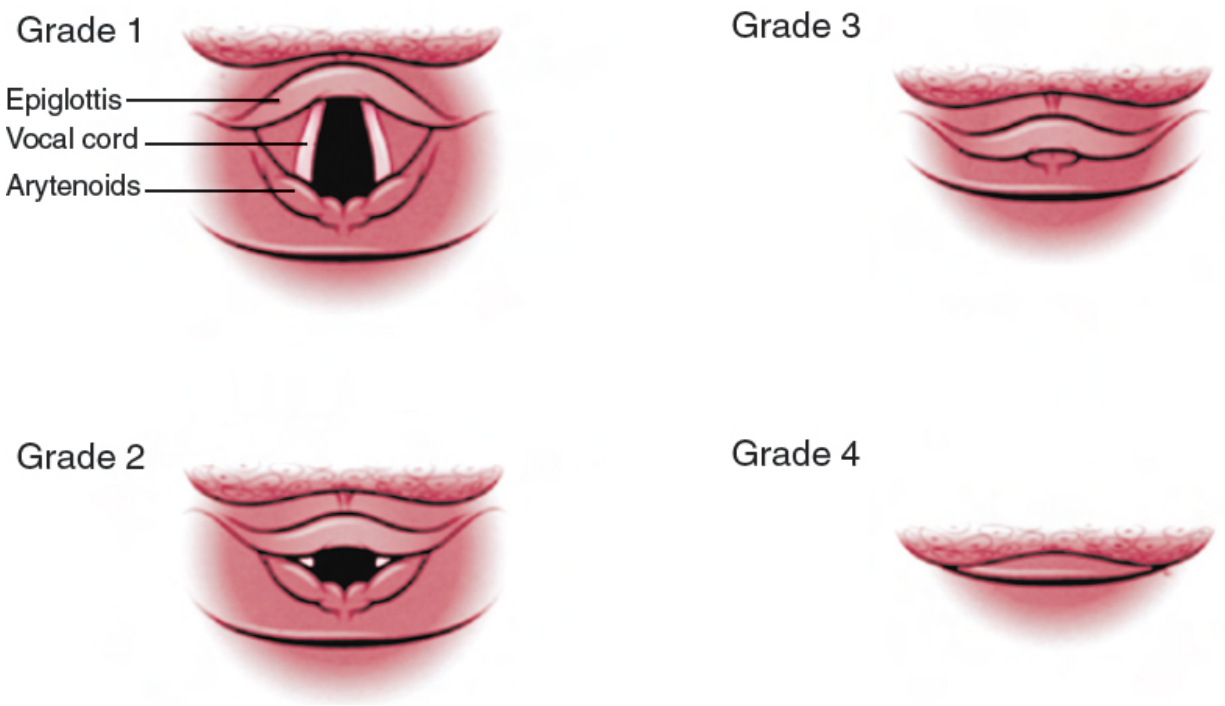

Figure 2.2: Cormack-Lehane laryngeal view grading system.

Despite scores of clinical studies, no evidence to date has identified a foolproof set of patient attributes that, when absent, always predicts successful intubation and, when present, predicts certain intubation failure. In the absence of a proven and validated system that can predict intubation difficulty with 100% sensitivity and specificity, it is important to develop an approach that will enable a clinician to quickly and simply identify those patients who *might* be difficult to intubate so an appropriate plan can be made using the difficult airway algorithm. In other words, when asking the question, “Does this patient’s airway warrant using the difficult airway algorithm or is it appropriate and safe to proceed directly to RSI?” we value sensitivity (ie, identifying all those who might be difficult) more than specificity (ie, always being correct when identifying a patient as difficult).

The mnemonic LEMON is a useful guide to identify as many of the anatomic risks of difficulty as quickly and reliably as possible to meet the demands of an emergency situation. The elements of the mnemonic are assembled from an analysis of the difficult airway prediction instruments in the anesthesia, emergency medicine, and critical care literature. The mnemonic, which we developed for The Difficult Airway Course and the first edition of this book, has been externally validated in emergency

department (ED) patients. The modified LEMON (all aspects of LEMON except the Mallampati score and thyromental distance) has undergone additional external validation and been found to have very high negative predictive value for both conventional laryngoscopy and VL. LEMON has now been adopted as a recommended airway assessment tool in the Advanced Trauma Life Support (ATLS) manual. When a complete or near-complete LEMON assessment is not possible because of patient acuity or obtundation, a single thyromental height (TMH) can be measured and, if <5 cm, identifies patients with challenging laryngoscopy with decent sensitivity and specificity (see "Evidence" section that follows).

The mnemonic is as follows:

L—*Look externally:* Although a gestalt of difficult intubation is not particularly sensitive (meaning that many difficult airways are not readily apparent externally), it is quite specific, meaning that if the airway looks difficult, it probably is. Most of the litany of physical features associated with difficult laryngoscopy and intubation (eg, small mandible, large tongue, large teeth, and short neck) are accounted for by the remaining elements of LEMON and so do not need to be specifically recalled or sought, which can be a difficult memory challenge in a critical situation. The external look specified here is for the "feeling" that the airway will be difficult. This feeling may be driven by a specific finding, such as external evidence of lower facial disruption and bleeding that might make intubation difficult, or it might be the ill-defined composite impression of the patient, such as the obese, agitated patient with a short neck and small mouth, whose airway appears formidable even before any formal evaluation (the rest of the LEMON attributes) is undertaken. This "gestalt" of the patient is influenced by patient attributes, the setting, and clinician expertise and experience, and likely is as valid for VL as for DL.

E—*Evaluate 3-3-2:* This step is an amalgamation of the much-studied geometric considerations that relate mouth opening and the size of the mandible to the position of the larynx in the neck in terms of likelihood of successful visualization of the glottis by DL. This concept originally was identified with "thyromental distance," but has become more sophisticated over time. The thyromental distance is the hypotenuse of a right triangle, the two legs being the anteroposterior dimension of the mandibular space, and the interval between the chin-neck junction (roughly the position of the hyoid bone indicating the posterior limit of the tongue) and the top of the larynx, indicated by the thyroid notch. The 3-3-2 evaluation is derived from studies of geometric requirements for successful DL, that is, the ability of the operator to create a direct line of sight from outside the mouth to the glottis. It is unlikely it has any value in predicting difficult HA-VL, for which no straight line of sight is required. The premises of the 3-3-2 evaluation are as follows:

- The mouth must open adequately to permit visualization past the tongue when both the laryngoscope blade and the endotracheal tube are within the oral cavity.

- The mandible must be of sufficient size (length) to allow the tongue to be displaced fully into the submandibular space during DL.
- The glottis must be located a sufficient distance caudad to the base of the tongue that a direct line of sight can be created from outside the mouth to the vocal cords as the tongue is displaced inferiorly into the submandibular space.

The first "3," therefore, assesses mouth opening. A normal patient can open his or her mouth sufficiently to accommodate three of his or her own fingers between the upper and lower incisors (**Fig. 2.3A**). This is an approximate measurement as it would be unusual to ask an acutely ill or injured patient to stick three fingers in his or her mouth. If a patient can comply, ask if he or she can open the mouth as wide as possible. This will give a meaningful sense of whether the patient is able to open fully, partially, or not at all. The second "3" evaluates the length of the mandibular space by ensuring the patient's ability to accommodate three of his or her own fingers between the tip of the mentum and chin-neck junction (hyoid bone) (**Fig. 2.3B**). The "2" assesses the position of the glottis in relation to the base of the tongue. The space between the chin-neck junction (hyoid bone) and the thyroid notch should accommodate two of the patient's fingers (**Fig. 2.3C**). Thus, in the 3-3-2 rule, the first 3 assesses the adequacy of oral access, and the second 3 addresses the dimensions of the mandibular space to accommodate the tongue on DL. The ability to accommodate fewer than three fingers is associated with greater degrees of difficulty in visualizing the larynx at laryngoscopy: The former because the length of the oral axis is elongated, and the latter because the mandibular space may be too small to accommodate the tongue, requiring it to remain in the oral cavity or move posteriorly, obscuring the view of the glottis. Encroachment on the submandibular space by infiltrative conditions (eg, Ludwig angina) is identified during this evaluation. The final 2 identifies the location of the larynx in relation to the base of the tongue. If significantly more than two fingers are accommodated, meaning the larynx is distant from the base of the tongue, it may be difficult to reach or visualize the glottis on DL, particularly if a smaller blade size is used initially. Fewer than two fingers may mean that

the larynx is tucked up under the base of the tongue and may be difficult to expose. This condition is often imprecisely called an “anterior larynx.”

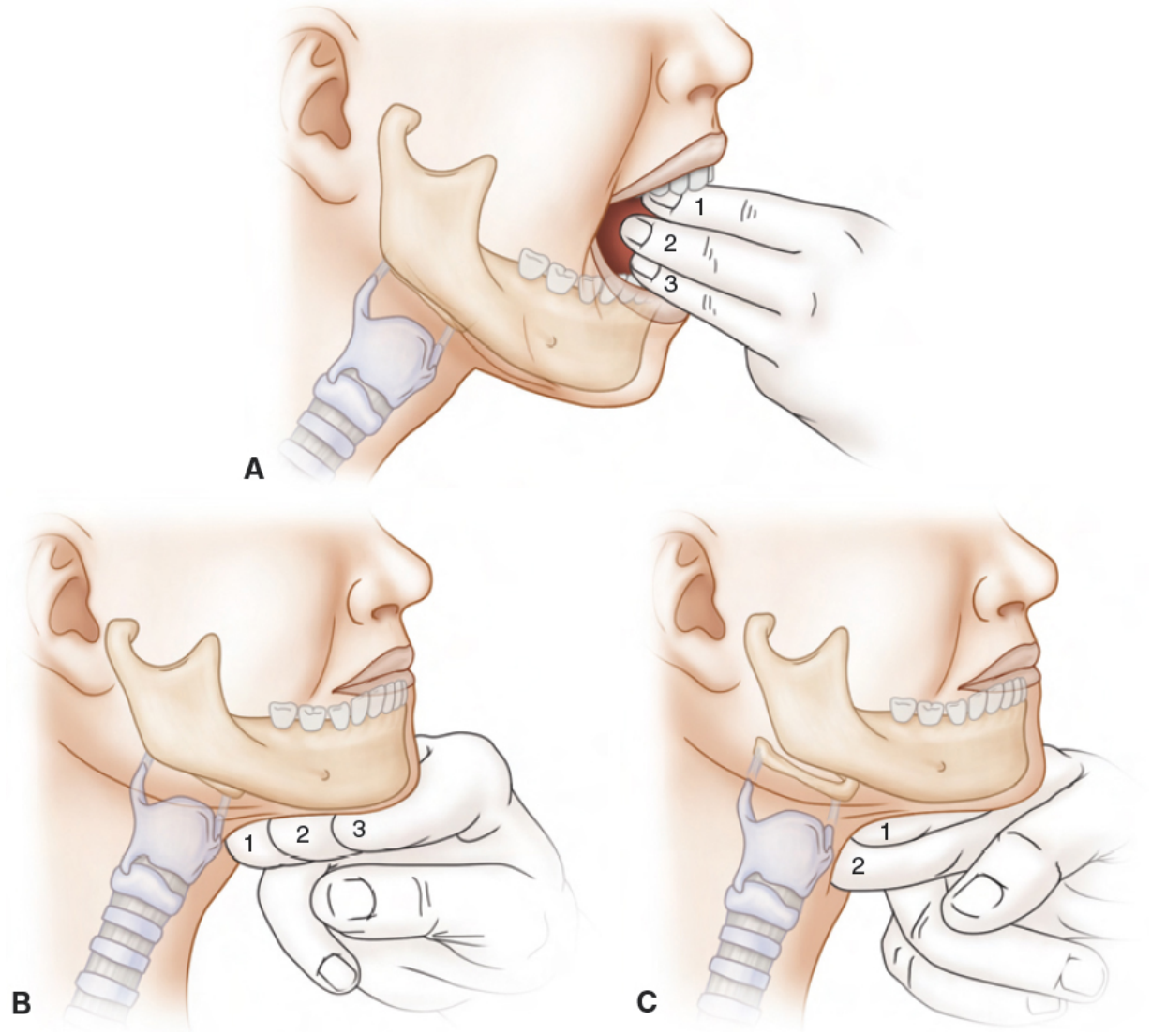

Figure 2.3: A: The first 3 of the 3-3-2 rule. B: The second 3 of the 3-3-2 rule. C: The 2 of the 3-3-2 rule.

M—*Mallampati score:* Mallampati determined that the degree to which the posterior oropharyngeal structures are visible when the mouth is fully open and the tongue is extruded reflects the relationships among mouth opening, the size of the tongue, and the size of the oral cavity and that these relationships are associated with intubation difficulty. Mallampati’s classic assessment requires that the patient sit upright, open the mouth as widely as possible, and protrude the tongue as far as possible without phonating. **Figure 2.4** depicts how the scale is constructed. Classes I and II patients have low intubation failure rates; so, the importance with respect to the decision whether to use neuromuscular blockade rests with those in classes III and IV, particularly class IV, where intubation failure rates may exceed 10%. By itself, the

scale is neither sensitive nor specific and not meant to be used as a stand-alone assessment; however, when used in conjunction with the other difficult airway assessments, it provides valuable information about access to the glottis through the oral cavity. In the emergency situation, it frequently is not possible to have the patient sit up or to follow instructions. Therefore, often only a crude Mallampati measure is possible, obtained by examining the supine, obtunded patient's mouth with a tongue blade and light, or by using a lighted laryngoscope blade as a tongue depressor on the anterior half of the tongue to gain an appreciation of how much mouth opening is present (at least in the preparalyzed state) and the relationship between the size of the tongue and that of the oral cavity. Although not validated in the supine position using this approach, there is no reason to expect that the assessment would be significantly less reliable than the original method with the patient sitting and performing the maneuver actively. The laryngoscope or tongue blade should not be inserted too deeply because this may incite a gag reflex and can place a supine and compromised patient at risk for vomiting and aspiration.

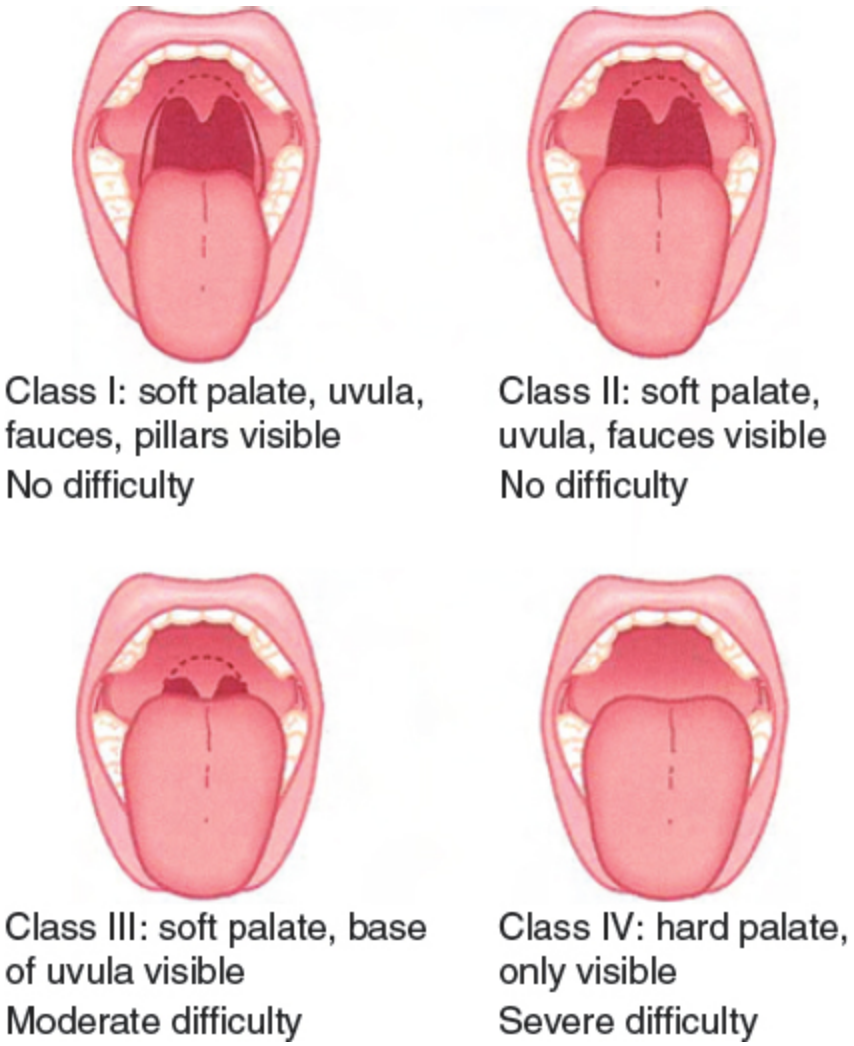

Figure 2.4: The Mallampati scale. In class I, the oropharynx, tonsillar pillars, and entire uvula are visible. In class II, the pillars are not visible. In class III, only a minimal portion of

the oropharyngeal wall is visible, and in class IV, the tongue is pressed against the hard palate.

O—*Obstruction/Obesity:* Upper airway obstruction is a marker for difficult laryngoscopy. The four cardinal signs of upper airway obstruction are muffled voice (hot potato voice), difficulty swallowing secretions (because of either pain or obstruction), stridor, and a sensation of dyspnea. The first two signs do not ordinarily herald imminent total upper airway obstruction in adults, but critical obstruction is much more imminent when the sensation of dyspnea occurs. Stridor is a particularly ominous sign. The presence of stridor is generally considered to indicate that the airway has been reduced to <50% of its normal caliber, or to a diameter of 4.5 mm or less. The management of patients with upper airway obstruction is discussed in Chapter 37. Although it is controversial whether obesity per se is an independent marker for difficult laryngoscopy or whether obesity simply is associated with various difficult airway attributes, such as high Mallampati score or failure of the 3-3-2 rule, obese patients frequently have poor glottic views by DL or VL, and obesity should be considered to portend difficult laryngoscopy.

N—*Neck mobility:* The ability to position the head and neck is one of the key factors in achieving the best possible view of the larynx by DL. Cervical spine immobilization for trauma, by itself, may not create a degree of difficulty that ultimately leads one to avoid RSI after applying the thought processes of the difficult airway algorithm. However, cervical spine immobilization will make intubation more difficult and will compound the effects of other identified difficult airway markers. In addition, intrinsic cervical spine immobility, as in cases of ankylosing spondylitis or rheumatoid arthritis, can make intubation by DL extremely difficult or impossible and should be considered a much more serious issue than the ubiquitous cervical collar (which mandates inline manual immobilization). VL requires much less (or no) head extension, depending on blade shape, and provides a glottic view superior to that by DL when head extension or neck flexion is restricted, particularly when HA-VL is used. Other angulated devices, such as the King Vision VL or Airtraq, discussed elsewhere in this manual, also may require less cervical spine movement than DL although image size and clarity are far inferior to that obtained with traditional VL units such as the GlideScope or C-MAC.

Difficult BMV: ROMAN

Chapter 12 highlights the importance of BMV in airway management, particularly as a rescue maneuver when orotracheal intubation has failed. The airway manager must be confident that oxygenation with a BMV or EGD is feasible before induction agents or neuromuscular blockers are administered, whether or not laryngoscopy and intubation are thought to be successful.

The validated indicators of difficult BMV from various clinical studies can be easily recalled for rapid use in the emergency setting by using the mnemonic ROMAN.

R—*Radiation/Restriction:* Evidence suggests that radiation treatment to the neck is one of the strongest predictors of difficult and failed mask ventilation. Restriction refers to patients

whose lungs and thoraces are resistant to ventilation and require high-ventilation pressures. These patients are primarily suffering from reactive airways disease with medium and small airways obstruction (asthma and chronic obstructive pulmonary disease [COPD]) and those with pulmonary edema, acute respiratory distress syndrome (ARDS), advanced pneumonia, or any other condition that reduces pulmonary compliance or increases airway resistance to BMV.

O—*Obesity/Obstruction/Obstructive sleep apnea:* We refer to this as the "triple O" because all three attributes are important, and they are often linked (eg, obesity with obstructive sleep apnea [OSA]). Patients who are obese (body mass index [BMI] >26 kg/m^2) are often difficult to ventilate adequately by BMV. Women in third-trimester gestation are also challenging to mask ventilate because of their increased body mass and the resistance to diaphragmatic excursion caused by the gravid uterus. Pregnant or obese patients also desaturate more quickly, making the bag ventilation difficulty of even greater import (see Chapters 38 and 43). Difficulty bagging the obese patient is not caused solely by the weight of the chest and abdominal walls but also the resistance by the abdominal contents to diaphragmatic excursion. Obese patients also have redundant tissues, creating resistance to airflow in the upper airway. This explains the recent association with OSA and difficult mask ventilation. Similarly, obstruction caused by angioedema, Ludwig angina, upper airway abscesses, epiglottitis, and other similar conditions will make BMV more difficult. In general, soft tissue lesions (eg, angioedema, croup, and epiglottis) are amenable to bag-and-mask rescue if obstruction occurs, but not with 100% certainty. Similarly, laryngospasm can usually be overcome with good bag-and-mask technique. In contrast, firm, immobile lesions such as hematomas, cancers, and foreign bodies are less amenable to rescue by BMV, which is unlikely to provide adequate ventilation or oxygenation if total obstruction arises in this context.

M—*Mask seal/Mallampati/Male sex:* Bushy beards, blood or debris on the face, or a disruption of lower facial continuity are the most common examples of conditions that may make an adequate mask seal difficult. Some experts recommend smearing a water based lubricant on the beard as a remedy to this problem, although this action may simply make a bad situation worse in that the entire face may become too slippery to hold the mask in place. Both male sex and a Mallampati class 3 or 4 airway also appear to be independent predictors of difficult BMV.

A—*Age:* Age greater than 55 years is associated with a higher risk of difficult BMV, perhaps because of a loss of muscle tone and tissue fullness in the face. The age is not a precise cutoff and some judgment can be applied with respect to whether the patient has relatively elastic (young) or inelastic (aged) tissue.

N—*No teeth:* An adequate mask seal may be difficult in the edentulous patient because the face may not adequately support the mask. An option is to leave dentures (if available) in situ for BMV and remove them for intubation. Alternatively, gauze dressings may be inserted into the cheek areas through the mouth to puff them out to improve the seal. Another technique for limiting mask leak involves rolling the lower lip down toward the chin and using the inner mucosal surface as a contact point for the bottom of the mask (see Chapter 12).

Difficult EGD: RODS

In the emergency setting, extraglottic airway devices are excellent first-line devices for ventilation and oxygenation, instead of the traditional bag and

mask; as alternatives to tracheal intubation in some patient circumstances (especially out of hospital); and as valuable rescue devices. Studies have identified factors that predict difficulty in placing an EGD and providing adequate gas exchange. These can be assessed using the mnemonic RODS.

R—*Restriction:* The restriction referred to here is like that for the ROMAN mnemonic, that is, "restricted" lung compliance or intrinsic resistance to ventilation from primary lung or tracheal/bronchial pathology. Ventilation with an EGD may be difficult or impossible in the face of substantial increases in airway resistance (eg, asthma) or decreases in pulmonary compliance (eg, pulmonary edema), although often the EGD is more effective at ventilation than is a bag and mask. In addition, restricted mouth opening will affect EGD insertion or make it impossible. Adequate mouth opening is required for insertion of the EGD. This requirement varies, depending on the EGD to be used. Recent operating room (OR) data have also identified restricted cervical spine mobility as a risk for difficult EGD use, likely because placement can be more challenging in these patients.

O—*Obstruction/Obesity:* If there is upper airway obstruction in the pharynx, at the level of the larynx or glottis, or below the vocal cords, an EGD may be impossible to insert or seat properly in order to achieve ventilation and oxygenation. In some circumstances, it will not bypass the obstruction at all. Obesity creates two challenges to oxygenation using an EGD. First, redundant tissues in the pharynx may make placement and seating of the device more difficult. Usually, this is not a significant problem. More importantly, obese patients require higher ventilation pressures, largely because of the weight of the chest wall and abdominal contents. The former causes resistance to ventilation by increasing the pressures required to expand the chest, and the latter causes resistance to ventilation by increasing the pressures required to cause the diaphragm to descend. Depending on the EGD chosen and positioning of the patient (it is better to attempt ventilation with the patient 30° head up or in reverse Trendelenburg position), ventilation resistance may exceed the ability of the EGD to seal and deliver the necessary pressures. More information on leak pressures for the variety of EGDs in circulation can be found in Chapter 13.

D—*Disrupted or Distorted airway:* The key question here is "If I insert this EGD into the pharynx of this patient, will the device be able to seat itself and seal properly within relatively normal anatomy?" For example, fixed flexion deformity of the spine, penetrating neck injury with hematoma, epiglottitis, and peri-laryngeal abscess each may distort the anatomy sufficiently to prevent proper positioning of the device.

S—*Short thyromental distance:* A small mandibular space, as assessed by the patient's thyromental distance, may indicate that the tongue resides less in the mandibular fossa and more in the oral cavity. This can obstruct and complicate EGD insertion and has been strongly associated with difficult EGD use.

Difficult Cricothyrotomy: SMART

There are no absolute contraindications to performing an emergency cricothyrotomy in adults (see Chapter 19). However, some conditions may make it difficult or impossible to perform the procedure, making it important to identify those conditions in advance and allow consideration of

alternatives rather than assuming that cricothyrotomy, if necessary, will be successful as a rescue technique. The mnemonic SMART is used to quickly assess the patient for features that indicate that a cricothyrotomy might be difficult. A part of patient assessment using this mnemonic, which occurs during the "A" step, is to perform a physical examination of the neck, identifying the landmarks and any barriers to the procedure. The SMART mnemonic is applied as follows:

S—*Surgery (recent or remote):* The anatomy may be subtlety or obviously distorted, making the airway landmarks difficult to identify. Scarring may fuse tissue planes and make the procedure more difficult. Recent surgery may have associated edema or bleeding, complicating performance of the procedure.

M—*Mass:* A hematoma (postoperative or traumatic), abscess, or any other mass in the pathway of the cricothyrotomy may make the procedure technically difficult, and requires the operator to meticulously locate the landmarks, which may be out of the midline, or obscured.

A—*Access/Anatomy:* Obesity makes surgical access challenging, as excess soft tissue makes it more difficult to identify landmarks. Additionally, the extra tissue forces the operator to work in a deep hole. Similar challenges are presented by subcutaneous emphysema, soft tissue infection, or edema. A patient with a short neck or overlying mandibular pannus presents challenges with both identification of landmarks and access to perform the procedure. External immobilization devices, such as a cervical immobilization collar, or a halo-thoracic brace also may impede access.

R—*Radiation (and other deformity or scarring):* Previous radiation therapy may distort and scar tissues, making the procedure difficult and often causing tissues that are normally discrete to bond together, distorting tissue planes and relationships.

T—*Tumor:* Tumor, either inside the airway (beware of the chronically hoarse patient) or encroaching on the airway, may present difficulty, both from access and bleeding perspectives.

TIPS AND PEARLS

- When intubation is indicated, the most important question is "Is this airway difficult?" The decision to perform RSI, for example, is based, in part, on a thorough assessment of anatomic difficulty (LEMON, ROMAN, RODS, and SMART) and appropriate use of the main or difficult airway algorithms. Most ED patients will have some degree of difficulty after a bedside assessment. The decision to perform RSI is a complex one that takes into account the degree of difficulty, the urgency for tube placement, the availability of difficult airway devices, especially VL, and one's own skill and experience. Basically, to use neuromuscular blocking agents (NMBAs), the operator must be

confident that oxygenation can be maintained, and that intubation is likely to be successful, using the planned approach.

- LEMON is a relevant screening tool for both difficult DL and VL. Even when elements of LEMON are found to be abnormal on bedside exam (ie, reduced cervical mobility secondary to a cervical collar), VL is still likely to succeed if the oral cavity is adequately accessible and not obliterated by massive soilage, significant anatomic distortion, or an obstructing mass.
- If LEMON and ROMAN are assessed first, in order, then each component of RODS also has been assessed, aside from the D: distorted anatomy. In other words, if LEMON and ROMAN have identified no difficulties, then all that remains for RODS is the question: "If I insert this EGD into the pharynx of this patient, will the device be able to seat itself and seal properly within relatively normal anatomy?"
- The ability to oxygenate a patient with a bag and mask or an EGD turns a potential "can't intubate, can't oxygenate" situation requiring urgent cricothyrotomy into a "can't intubate, *can* oxygenate" situation, in which many rescue options can be considered. The ability to prospectively identify situations in which oxygenation using an EGD or a bag and mask will be difficult or impossible is critical to the decision whether to use NMBAs.
- No single indicator, combination of indicators, or even weighted scoring system of indicators can be relied on to guarantee success or predict inevitable failure for oral intubation. Application of a systematic method to identify the difficult airway and then analysis of the situation to identify the best approach, given the anticipated degree of difficulty and the skill, experience, and judgment of the individual performing the intubation, will lead to the best decisions regarding how to manage the clinical situation. In general, it is better to err by identifying an airway as potentially difficult, only to subsequently find this not to be the case, than the converse.

EVIDENCE

What is the incidence of poor glottic view during emergency department intubation?

A poor glottic view is associated with low intubation success. The highest first-attempt success has historically been seen with a C-L grade I and II airways and is largely dependent on device. Recent data from the National Emergency Airway Registry (NEAR) have provided insight into the expected C-L view during ED intubation. In an analysis of nearly 12 000 patients intubated with either HA-VL or SG-VL, a C-L grade I or II view was obtained in 94.1% and 87.4%, respectively.[1] A second NEAR study, assessing the intubating conditions during RSI with either DL or VL observed a C-L grade I or II view in approximately 89% of all encounters. In this same study the first-attempt success rate was 87% to 88% with an ultimate success rate >99%.[2] In a single-center prospective evaluation of 750 ED intubations over a 2-year period, during which 255 intubations were performed with a C-MAC and the rest with a conventional laryngoscope, the C-MAC yielded grade I/II views in 94% of cases compared with 83% for DL.[3] On balance, emergency physicians can expect to obtain a C-L grade I or II view in 80% to 90% of patients when using DL but 90% to 95% with VL. The latter exhibits some variability depending on whether a SG or HA video laryngoscope is used.

What is the evidence basis of LEMON?

There is only one published external validation of the LEMON mnemonic and one for the modified LEMON.[4] The American College of Surgeons adopted the LEMON mnemonic for ATLS in 2008. In a multicenter prospective intubation registry in Japan, 3313 patients, for whom a difficult airway assessment was performed and who were intubated using DL, the modified LEMON had a sensitivity of 86% and a negative predictive value of 98% for difficult laryngoscopy.[5] Difficult intubation was defined as any encounter requiring two or more attempts. In other words, the LEMON assessment is most helpful when completely normal and indicates that nearly all patients would be candidates for RSI if truly LEMON-negative. Individual elements, taken in isolation, are less helpful and should not constitute the basis of a difficult airway assessment. However, in an uncooperative or obtunded patient in whom many of the elements of

LEMON cannot be performed, a single measurement of the TMH performs well compared to other single bedside tests. It does not require head movement, patient cooperation, or sophisticated measuring tools. With the patient in neutral head position, a TMH of <5 cm identified challenging laryngoscopy with 77% sensitivity and 84% specificity, better than any other single bedside test.[6] The gestalt of difficulty provided by the patient is an intuitive notion and will vary greatly with the skills and experience of the intubator. There are no studies, of which we are aware, that assess the sensitivity or specificity of this first, quick look. We are not aware of the true origin of the 3-3-2 rule. It probably originated from a group of Canadian difficult airway experts, led by Edward Crosby, MD, but, to our knowledge, it was not published before we included it in the first edition of our book in 2000. The modified Mallampati score, the four-category method that is most familiar, is known to be reliable but while the test is important, it is not sufficient in fully evaluating the difficult airway and cannot be performed in roughly half of all ED patients requiring intubation. Interference with DL by upper airway obstruction is self-evident. Obesity is uniformly identified as a difficult airway marker controversy persists regarding whether obesity, per se, indicates difficult laryngoscopy, or whether obese patients simply have a greater incidence of having other difficult airway markers, such as higher Mallampati scores.

What is the evidence basis of ROMAN?

The first well-designed study of difficult BMV reported a 5% incidence of difficult BMV in 1502 patients in the OR. They identified five independent predictors of difficult BMV: presence of a beard, high BMI, age >55 years, edentulousness, and a history of snoring. Subsequent studies by other investigators were much larger. Kheterpal et al used a graded definition of difficult BMV in their study of >22 000 patients. They divided difficult BMV into four classes, ranging from routine and easy (class I) to impossible (class IV). Class III difficulty was defined as inadequate, “unstable,” or requiring two providers. They identified class III (difficult) BMV in 313/22 600 (1.4%) and class IV (impossible) in 37 (0.16%) patients. Multivariate analysis was used to identify independent predictors of difficult BMV: presence of a beard, high BMI, age >57 years, Mallampati class III or IV, limited jaw protrusion, and snoring. Snoring and

thyromental distance <6 cm were independent predictors of impossible BMV.[7] Subsequently, the same researchers studied 53 041 patients over a 4-year period. Independent predictors of impossible BMV included the following: presence of a beard, male sex, neck radiation changes, Mallampati class III or IV, and sleep apnea, with neck radiation having the strongest association of failed mask ventilation.[8] These studies, combined with others, and with our collective experience, are the foundation for the ROMAN mnemonic.

What is the evidence basis of RODS?

Most EGDs have not been systematically studied for predictors of difficulty. Previous information came from case reports or small case series. A large OR-based registry of 14 480 adult patients managed with either an LMA or an i-gel showed that successful oxygenation and ventilation occurred in nearly all (99.8%) cases. Multivariable analysis identified four factors predictive of difficulty: short thyromental distance, male sex, limited neck movement, and age, with short thyromental distance having the highest odds of difficulty (adjusted odds ratio [aOR] 4.4).[9] Interestingly, obesity was not predictive. We hesitate to remove obesity from the RODS mnemonic, however, because this study had very few difficult cases and because it has been shown previously to affect rescue mask ventilation. As such, this mnemonic really represents our expert consensus and commonsense conclusions rather than an assessment of high-quality evidence. The requirement for minimal mouth opening sufficient to insert the device is self-evident. Obesity and obstruction will interfere with EGD use in similar fashion to their interference with BMV. Devices vary in their utility in various patients, however, and some, particularly those with higher leak pressures, may be better suited for obese patients. Distorted anatomy is our own concept, because each of these devices is designed to “seat” into normal human anatomy, given that the right size of device is selected.

Does LEMON apply to VL and are there other difficult airway mnemonics in use?

Much of LEMON has to do with the need to see past the tongue, to the glottis, using a straight line of sight. VL, particularly HA-VL, does not require a straight line of sight, so, for example, we do not have any reason

to believe that abnormalities discovered during a 3-3-2 assessment applies to hyperangulated video laryngoscopes. In one study comparing the C-MAC video laryngoscope with DL in ED intubations, the aggregate effect of multiple difficult airway markers had a significant impact on first-pass success with DL but not with VL. Comparing first-attempt success between patients without difficult airway markers with those that had three or more, the first-attempt success for DL decreased from 88% to 75% but decreased only by 5% for VL (99% - 93%).[3] Mallampati is not nearly as important, because the video viewer on most video laryngoscopes is positioned beyond the tongue, thus eliminating the tongue from consideration. Mallampati assesses mouth opening also, however, as does the first "3" of the 3-3-2 rule, and mouth opening remains important for VL, although much less so. The mnemonic "CRANE" (*C*ontamination and C-L 3 or 4 with DL, *R*adiation, *A*bnormal anatomy: mass; previous surgery; decreased mouth opening, *N*eck thick, *E*piglottitis or enlarged tongue) has been used by some to help identify potential challenges (in OR patients) with VL.[10] As previously mentioned above, the utility of this mnemonic for emergency airway management is questionable. In the OR, when VL is thought to be challenging, the threshold for performing an awake flexible intubation is much lower given patient stability, familiarity by anesthesiologists with awake techniques, and availability of flexible endoscopic tools. A more practical approach in ED patients is to first determine if orotracheal intubation is possible or doomed to fail because of overwhelming soilage, drastically reduced mouth opening, or large obstructing oral and upper airway pathology. If orotracheal intubation is planned and thought to be feasible, then VL should be used whenever possible and a LEMON assessment, if abnormal, will further support that decision. A second alternative mnemonic, "HEAVEN" (*H*ypoxemia, *E*xtremes of size, *A*natomic challenges, *V*omit/blood/fluid in the airway, *E*xsanguination, and *N*eck mobility) has been shown, in a retrospective review of aeromedical RSIs, to predict difficulty with both VL and DL. However, the components of HEAVEN are either excessively vague ("extremes of size" and "anatomic challenges") or self-evident (blood/vomit in the airway) and do not have sufficient detail or specificity to have utility at the bedside.[11]

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CHAPTER 3

The Physiologically Difficult Airway

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DEFINITION OF THE PHYSIOLOGICALLY DIFFICULT AIRWAY

Critically ill patients present a unique danger during airway management. The risk with intubation-related complications was traditionally thought to be largely a result of anatomic challenges that confound attempts at intubation and leave a patient without an unsecured airway or effective respiration for a prolonged period. Reducing that risk was intimately tied to laryngoscopy device and skill and if, for example, a patient with refractory hypoxemia needed intubation, the mindset was to “do what you are best at” and do it quickly before the patient arrests. The fact that the risk of complications increases after a single missed attempt only reinforces the urge to fall back on laryngoscopy skills to race the impending cardiac arrest. Thankfully, over the last 15 years, video laryngoscopy, second-generation supraglottic airway devices, and disposable flexible endoscopes have largely overcome the challenges posed by anatomic obstacles to laryngoscopy and rescue ventilation. Yet, despite all the technological devices available to us resulting in higher success rates, there are still unsettlingly high rates of desaturation, hypotension, and cardiac arrest during emergency airway management. Although difficult intubations dramatically increase the risks of these complications, a recent study showed half of all critically ill patients had complications despite only a 5% difficult intubation incidence (see “Evidence” section). This risk is caused by cardiopulmonary decompensation during intubation from physiologic

disturbances despite the presence or absence of anatomic challenges to intubation—*the physiologically difficult airway*.

PREDICTING THE PHYSIOLOGICALLY DIFFICULT AIRWAY

There are myriad reasons why a patient may decompensate from physiologic derangement during intubation. Abnormalities in isolation, or in combination, are exacerbated by intubation drugs, apnea, and the transition to positive pressure ventilation (PPV) and together affect the patient's cardiopulmonary status. The most seen preintubation abnormalities that should be considered are summarized by the CRASH mnemonic (**Box 3.1**).

BOX 3.1 The CRASH The CRASH Mnemonic

	Physiologic Abnormality	**Response**
C	Increased oxygen **C**onsumption	Optimize preoxygenation, apneic oxygenation
R	**R**ight ventricular failure	Optimize preoxygenation, inhaled pulmonary vasodilators, choice of induction agents, early use of vasopressors
A	**A**cidosis (Metabolic)	Correct underlying issues, avoid mechanical ventilation if possible, minimize apnea time, consider awake intubation, maintain increased minute ventilation
S	Risk of de**S**aturation	Optimize preoxygenation
H	**H**ypotension	Volume resuscitation, vasopressors

Consumption: Pediatric patients, sepsis, acute respiratory distress syndrome (ARDS), or other high-demand states such as excited delirium, thyrotoxicosis, and pregnancy all increase the consumption of oxygen. Although there is redundancy in oxygen delivery to meet this demand (thus why normal SvO_2 is 75% and not 0%), patients at or near their anaerobic threshold with a critical illness that increases oxygen consumption and decreases oxygen delivery are at risk of rapid desaturation despite normal or near normal oxygen saturation during preoxygenation.

Right Ventricular Dysfunction/Failure: Patients with right ventricular (RV) dysfunction or failure are at very high risk of decompensation during intubation. The right ventricle has very little reserve to overcome increased afterload. Early on, the right ventricle can increase contractility through interventricular dependence with the left ventricle, but as dilation and regurgitant flow across the tricuspid valve worsens, contractility worsens, and further dilation eventually

impairs left ventricular diastolic filling. Cardiac output is only maintained by tachycardia at this point, and any further increase in RV afterload, or further volume loading of the right ventricle, can push the right ventricle too far and result in cardiac arrest. Hypercapnia, atelectasis, hypoxemia all independently increase pulmonary vascular resistance, and positive pressure can increase RV afterload as well—often to the point of cardiovascular collapse.

Acidosis: Severe metabolic acidemia increases risk by further decreasing the pH with any interruption of compensatory ventilation during intubation or unmatched alveolar ventilation requirement after intubation. Although many patients can increase their $PaCO_2$ during intubation, those trying to compensate for a severe metabolic acidosis can be tipped over the edge during this brief period. Profound acidosis can have negative inotropic effects on the heart, worsen shock states, and instigate malignant ventricular dysrhythmias.

Saturation: Critically ill patients with airspace diseases such as ARDS have limitations in the ability to preoxygenate to provide an adequate safe apnea duration. Preoxygenation should address the three components required for a safe apneic interval: denitrogenation, improving functional residual capacity (FRC), and reducing ventilation/perfusion mismatch. Monitoring end-tidal oxygen (ETO_2) can assist in ensuring optimal denitrogenation, which is best performed with a tight-fitting mask and 100% flush-flow rate oxygen, or heated high-flow nasal oxygen (HFNO; see Chapter 8). In patients where safe apnea is limited or not possible, the strategy should be changed to accommodate the potential for rapid desaturation.

Hypotension/volume: Critically ill patients are at significant risk of peri-intubation hypotension from many factors. Volume depletion, vasoplegia, and cardiomyopathy are all relatively easily identified and steps can be taken to address them prior to intubation. The response to induction agents and positive pressure are more difficult to predict and when combined with any of the former increase the risk of precipitating a decompensated state. An elevated shock index (SI) is helpful to predict those patients at high risk, but a low SI should not necessarily be reassuring.

PREPARATION FOR THE PHYSIOLOGICALLY DIFFICULT AIRWAY

After assessing for anatomic difficulty (eg, “LEMON,” “ROMAN,” “RODS,” and “SMART” mnemonics, see Chapter 2), one generally has an idea who is eligible for rapid sequence intubation (RSI) based on the predicted success with laryngoscopy, intubation, bag-mask ventilation, and rescue strategies or who is forced to be intubated with RSI despite anatomic challenges (ie, “forced to act,” see Chapter 5). After the airway anatomy has been assessed, the patient’s physiologic vulnerability is evaluated for potential decompensation (eg, “CRASH”) during intubation. After assessing the physiology, the following questions should be addressed?

- **What can I do to augment the physiology and proceed with my strategy (ie, RSI)?** For example, intubation drug choice, positioning, preoxygenation maneuvers, etc.

- **Do I need to change my strategy because of physiology that is refractory to intervention?** For example, intubate awake because of refractory hypoxemia?

After the general strategy is determined, specific plans within the strategy are developed.

MANAGING THE PHYSIOLOGICALLY DIFFICULT AIRWAY

Oxygenation

The goal of preoxygenation is to build an oxygen reservoir for the patient to draw upon during apnea and maintain oxygen saturation. Successful preoxygenation is dependent on three components: (i) a volume of gas to work with (FRC), (ii) replacement of that gas with oxygen (denitrogenation), and (iii) availability of that volume to the pulmonary circulation (minimized ventilation/perfusion [V/Q] mismatch and shunt). One or a combination of abnormalities of those necessary requirements limits the goal of achieving time for laryngoscopy, intubation, and initiation of mechanical ventilation. For example, patients with severe ARDS can be easily denitrogenated, but a small volume FRC and low V/Q (high shunt) dramatically reduces the time available for intubation. High oxygen consumption also increases the rate at which that reservoir of oxygen is consumed. This is primarily driven by the patient's illness and is difficult to manipulate in the peri-intubation period. Preventing desaturation is a critical step for the safety of emergency airway management. "Racing" hypoxemia by attempting a fast intubation as a "forced to act," while tempting in a stressful situation, is fraught with danger for many patients such as refractory hypoxemia and ARDS. Although you may get lucky and the oxygen saturation would not have dropped critically during the attempt, it could plummet even before intubating conditions are creating by the RSI drugs. The oxygen saturation inevitably drops after the attempt as the desaturated blood passing through the pulmonary circulation makes it to the oxygen saturation sensor on the finger. If any unexpected delay occurs (eg, challenging and prolonged laryngoscopy), this may be the tipping point into

a bradycardic arrest. The safest option is to optimize the three necessary variables for preoxygenation.

Functional Residual Capacity

As there is no tidal breathing during apnea, by definition, the reservoir of gas available is that which is present in the lungs at the end of end-expiration and is called the FRC. The FRC is dependent on height and age. In a healthy adult, the FRC is roughly 25 to 30 mL/kg, resulting in around 2 L in a 70-kg adult. Anything that compresses or fills the alveoli will reduce the FRC. Thoracic or abdominal fat, ascites, or late-term gravid uteri all compress the alveoli externally, whereas hemorrhage, pneumonia, edema, and ARDS all obliterate airspace internally. In patients intubated for pneumonia or other causes of hypoxemia, or in patients with ascites, late-term pregnancy, pleural effusions, and obesity, the FRC is often the limiting factor in preoxygenation. In these cases, consider interventions in **Box 3.2** to increase the FRC.

BOX 3.2 The CRASH Variables for Preoxygenation

Limiting Factor	Intervention
Reduced functional residual capacity	1. Position the patient upright. 2. Recruit any recruitable alveoli (ie, Bi-PAP).
Denitrogenation	1. Use flush rate oxygen via nonrebreathing mask or high-flow nasal cannula. 2. Monitor with ETO_2, if available. 3. Keep the source of oxygen in place until the patient is apneic. 4. Controlled bag-mask ventilation between induction and laryngoscopy in patients at low risk for aspiration. 5. Apneic oxygenation with standard nasal tubing at 5-15 L/min.
V/Q mismatch (shunt)	1. Reduce work of breathing and recruit alveoli with high-flow nasal oxygen or NIPPV. 2. Diurese patients with significant pulmonary edema.

Bi-PAP, bi-level positive airway pressure; ETO_2, end-tidal oxygen; NIPPV, noninvasive positive pressure ventilation.

Denitrogenation

Denitrogenating the FRC and replacing it with oxygen will maximize the potential amount of oxygen available during apnea. Denitrogenation can be accomplished with 3 minutes of tidal breathing or eight vital capacity breaths if the patient is breathing on a closed circuit and 100% F_{IO_2} (assuming a normal respiratory rate and tidal volume). In emergency airway management, closed circuits are rarely available and most oxygen sources available using conventional oxygen therapy involve loosely fitting reservoir-based nonrebreather masks. Although the oxygen flowing into the reservoir is constant, which increases the F_{IO_2} and volume available during inspiration, the inspiratory flow rate generated by the patient leads to room air entrainment around the nonrebreather mask, contaminating the inspired volume with ambient air. As the inspiratory flow generated by the patient often increases with the severity of respiratory failure, ambient air entrainment worsens as respiratory effort increases. The result is that ambient room air dilutes the FRC, and the severity of this dilution increases in patients that need to increase F_{IO_2} the most.

The best way to compensate for the entrainment of ambient room air in the absence of a closed circuit is to use “flush-flow rate” flow through a wide-open valve (see Chapters 8 and 20). The more pressurized the hospital’s oxygen system, the higher the flow will be achieved at flush rate. Flush rate can be as high as 90 L/min or more, which provides enough flow to more closely approximate the inspiratory flow rate of the critically ill patient with a high respiratory demand breathing supplemental oxygen with an open circuit. One important consideration is that any spontaneous breaths after removing the source of oxygen can result in rapid renitrogenation, thus the patient should be fully apneic before removing the oxygen source.

The effect of denitrogenation can be prolonged, theoretically indefinitely, with the application of oxygen continuously to the nasopharynx during apnea. The ability to maintain alveolar oxygenation during apnea, or apneic oxygenation, is contingent upon the pressure gradient between the nasopharynx and the alveoli, which is a function of the amount of flow applied and the rate of peripheral oxygen consumption. This passive flow of oxygen from the glottic inlet to the gas-exchanging portions of the lungs is known as “aventilatory mass flow” and is discussed

in more detail in Chapter 8. Thus, apneic oxygenation performed using HFNO systems, such as Vapotherm or Optiflow, is expected to perform better than apneic oxygenation using 10 to 15 L/min from a standard nasal cannula. Apneic oxygenation has been shown to lengthen the period of safe apnea and increase first-attempt success (secondary to more laryngoscopy time) although it does not perform as well in patients with significant V/Q mismatch. Interventions for denitrogenation are found in Box 3.2.

V/Q Mismatch

A fully denitrogenated patient with an FRC of 2 L and an oxygen consumption of 250 mL/min should have several minutes of safe apnea. This, however, requires that this reservoir of oxygen is fully available to the pulmonary circulation. There are normal V/Q differences in the lung because of gravity, such that the apices have more ventilation than perfusion (dead space) and the bases are the opposite (shunt). However, the global V/Q mismatch is minimal, with a normal shunt fraction of roughly 2%, meaning that a fully denitrogenated FRC is widely available to resaturate hemoglobin as it passes through the pulmonary circulation.

As airspace or interstitial disease worsens, however, the alveolar-arterial gradient increases and V/Q mismatch moves toward the shunt end of the spectrum, which means that even though maximal alveolar oxygenation can still be achieved, oxygen is less available at the alveolar-capillary interface to resaturate hemoglobin. In emergency department (ED) patients, the V/Q mismatch can be improved by recruiting atelectatic regions of the lung with positive end-expiratory pressure (PEEP), reducing interstitial edema with diuresis, or improving myocardial performance in the case of cardiogenic pulmonary edema. Inhaled pulmonary vasodilators, often used in the intensive care unit (ICU), can be helpful in some cases. Occasionally, decreased lung compliance and the airspace disease is refractory to any effort at improving V/Q mismatch. This results in a small available FRC despite being fully denitrogenated.

Who Should Be Intubated Awake?

In the most refractory cases, preoxygenation fails to provide an adequately available reservoir of oxygen and an acceptable safe apnea time is not

possible. In these patients, an awake intubation with continuous high-flow oxygen may be the safest path to securing the airway to initiate invasive mechanical ventilation. The risk of critical desaturation and cardiac arrest is significantly high enough in these patients that one should strongly consider an awake approach. The decision is more difficult in patients that have improved with noninvasive respiratory support. At the end of the preoxygenation process in these patients with hypoxemic respiratory failure, where any recruitable alveoli have been recruited, the FRC is maximized as much as possible and fully denitrogenated, the partial pressure of arterial oxygen (PaO_2) from an arterial blood gas (ABG) can provide a good assessment of the degree of shunt. Although the PaO_2 does not contribute substantively to oxygen delivery, in this instance it is a good indicator of oxygen availability in the alveoli to the pulmonary circulation, and thus safe apnea time. Consider two patients with ARDS that are preoxygenated using identical methods, both with an oxygen saturation of 95%. The first patient's PaO_2 is 220 mmH_2O and the second patient's PaO_2 is 79 mmH_2O. Despite the same oxygen saturation, the second patient's oxygen reservoir is far less available to resaturate hemoglobin and very likely to desaturate rapidly upon induction.

How Do I Stratify Preoxygenation?

During an emergency intubation, preoxygenation is the most important preinduction step as safe apnea is paramount for patient safety during RSI. Although denitrogenation can easily be quantified by measuring ETO_2, the patient's total oxygen reserve (FRC) is hard to measure and the oxygen saturation only tells part of the story, as mentioned above. Although a strategy involving ABG sampling is often undertaken in the ICU, it can be impractical and logistically challenging to accomplish in the context of a deteriorating hypoxemic emergency department patient. In practice, it can be helpful to place patients into one of three categories based on their ease of preoxygenation. The default approach is to place the patient upright or in reverse Trendelenburg position and apply standard nasal cannula along with a nonrebreather mask using flush rate oxygen. If the saturation is below 94%, then there is significant intrapulmonary shunt, and the patient should be transitioned to HFNO or bi-level positive airway pressure (Bi-PAP) to

reduce the shunt fraction and improve the SaO_2. In these patients, even if the saturation improves, the total oxygen reserves and, therefore, duration of safe apnea is not known. If temporarily stabilized while preoxygenating on HFNO or Bi-PAP *and* an ABG is easily obtained, then a PaO_2:FIO_2 ratio can inform the clinician as to who is at highest risk of dangerous desaturation with RSI despite the improved saturation. A PaO_2:FIO_2 ratio <100 indicates a very high-risk situation and an awake approach is preferred. If, despite noninvasive positive pressure ventilation (NIPPV) or HFNO, the patient remains <94%, critical hypoxemia will occur during RSI and may be evident even before sedative and neuromuscular blocking agents have taken effect. Similarly, these patients are best intubated using awake techniques (see Chapter 24).

Hemodynamics

Hemodynamic challenges have risen as the pinnacle source of danger to patients requiring intubation in the ED or ICU. In a recent worldwide study across 29 countries, less than 10% of patients were intubated for hemodynamic instability but almost half developed hemodynamic instability as a result of the intubation. Thus, preintubation management of patients' hemodynamics are as important as preoxygenation for emergency airway management. Unfortunately, hemodynamic disturbances are as, or more, complex than hypoxemia. The overarching goal is to safely transition a patient, often with limited or no reserve, through apnea and laryngoscopy to PPV. To accomplish that, we most commonly use medications that blunt the survival (sympathetic) drive and often have hemodynamic consequences of their own. With 1 in 3 patients suffering cardiovascular collapse and nearly 1 in 30 a cardiac arrest, emergency airway management must include peri-intubation management of hemodynamics.

The evidence for optimizing hemodynamics is challenged by a lack of standardized definitions regarding vital sign thresholds or the peri-intubation period. Despite these limitations, observational data show that preintubation shock index (SI, heart rate/systolic blood pressure), older age, hypotension, shock, intubation for respiratory failure and a higher severity of illness (APACHE) score are all factors associated with a higher likelihood of postintubation cardiovascular collapse. Various methods to

reduce hypotension rates have been attempted or debated as long as critically ill patients have required intubation. Early on, patient positioning was altered to overcome hypotension associated with thiopental. Etomidate and ketamine have been debated for 20 years. Bolus-dose vasopressors and fluid resuscitation strategies have been proposed, and debated, without definitive evidence for either of these interventions. Resuscitation, when used as a part of a bundle in the perioperative period has been shown to reduce complications. Blood products prior to intubation in trauma patients has also been shown to improve outcomes. Unfortunately, none of these findings have been reproducible, illustrating the complex pathophysiologic disturbances that require personalization for each patient.

Consider the following example to demonstrate this complex milieu: a patient with severe ARDS. There is significant airspace disease resulting in the loss of FRC as described in the “Oxygenation” section. That worsens ventilation/perfusion ratios to make preoxygenation more difficult, but also increases the pulmonary vascular resistance and increases the strain on the right ventricle. Any hypercapnia or hypoxemia that occurs during apnea can further increase the pulmonary vascular resistance, and when added to any induction agent-induced venodilation or myocardial depression, or positive pressure induced reduction in preload, can lead to a precipitous cardiovascular collapse. The same phenomenon can occur with patients with massive pulmonary embolism, decompensated pulmonary hypertension, or cardiac tamponade. Septic patients lie on a spectrum from vasodilation and high cardiac output to high systemic vascular resistance and myocardial depression. Patients with heart failure with preserved ejection fraction have high left ventricular filling pressures and high pulmonary venous pressures leading to pulmonary edema, whereas patients with heart failure with reduced ejection fraction have poor contractility leading to high pulmonary venous pressures and pulmonary edema. Although all of these patients may present with hypoxemia, respiratory failure, and hypotension, the management for each of them needs to be tailored to attenuate the physiologic weakness (**Figure 3.1**). Vasoplegia is a major factor contributing to the negative hemodynamic effects seen in the peri-intubation period and may not be easily measured or adequately addressed. Additionally, the choice of induction agents and vasoactive medications further adds to these myriad factors. Any of these factors may

be responsible for cardiovascular collapse in a fragile, critically ill patient. As such, these dynamic cardiopulmonary changes are challenging to predict, understand, and optimize. We offer a stepwise hemodynamic approach.

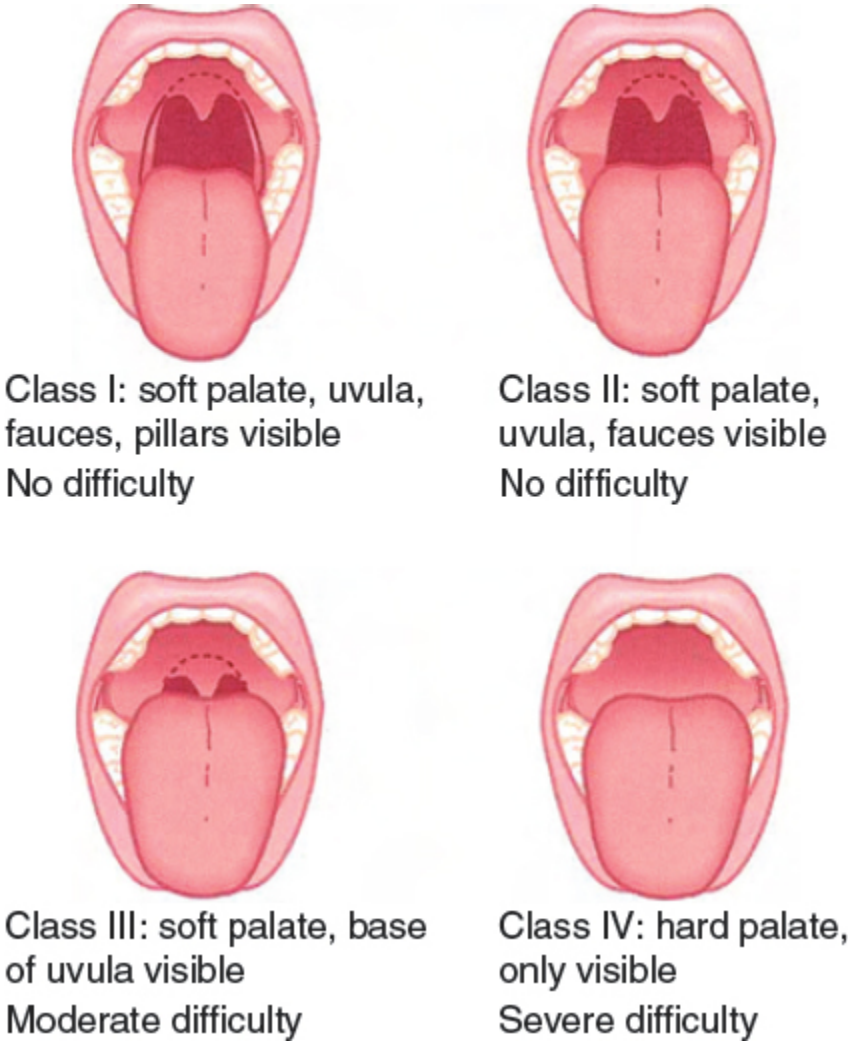

Figure 3.1: Factors affecting hemodynamics during intubation. Respiratory factors include the effects of positive pressure ventilation (PPV), desaturation, or hypercapnia which all increase pulmonary vascular resistance and right ventricular (RV) afterload, whereas inhaled nitric oxide (iNO) vasodilates the pulmonary circulation and decreases RV afterload. Fluids can often increase stressed volume, whereas sedatives have varying effects. Propofol and midazolam can decrease the stressed volume, thereby increasing the unstressed volume and decreasing the preload. Etomidate can decrease arterial elastance causing hypotension. Propofol can cause arterial dilation and depression of left ventricular (LV) contractility, whereas ketamine can cause arterial constriction and increased LV contractility through its indirect sympathomimetic effect, or LV suppression though its

myocardial depressant effect. Vasopressors affect the cardiovascular system dependent on their potency and receptor profile.

Stepwise Hemodynamic Strategy

There are many factors that can collude to cause postintubation cardiovascular collapse. Thus, there is no one-size-fits-all approach to hemodynamic assessment or resuscitation prior to intubation. There is no single induction agent that can eliminate concern of the underlying pathophysiology and no vasopressor that can eliminate peri-intubation deterioration. Volume depletion, vasoplegia, ventricular performance, hemodynamic effects of induction agents, and PPV are all important factors that need to be carefully considered. There are several concepts that can lead to a stepwise hemodynamic strategy with emergency airway management.

1. **Replete volume loss:** Most critically ill patients are volume depleted, either through fluid or blood loss, insensible losses, or fluid shifts. Thus, most patients require some form of fluid resuscitation. Methods for assessing volume responsiveness, or volume tolerance, are beyond the scope of this chapter—but there are many easily available and easy to perform methods to assess both. In patients who are likely to be volume responsive, fluid resuscitation should be performed. The type and volume of fluid will be dependent on the underlying pathophysiology and severity. The goal is to increase the circulating stressed volume. The stressed volume is the circulating volume that exerts a pressure against the vascular walls, and thus contributes to blood pressure, cardiac output, and oxygen delivery. Fluid resuscitation that does not lead to an increase in cardiac output or blood pressure is contributing to unstressed volume, which is volume that is stored in the high capacitance venous system.
2. **Reduce unstressed volume and vasoplegia:** Any fluid bolus that does not contribute to increased cardiac output is fluid stored as unstressed volume. Additionally, venodilating induction agents convert stressed volume into unstressed volume. Thus, patients not responsive to fluid resuscitation should be started on vasopressor infusions to reduce

unstressed volume with vasoconstriction—particularly venoconstriction.

Patients with a SI ≥0.8 are at high risk of developing postintubation hypotension. Individual vital signs that are not alarming in isolation, such as a heart rate of 100 and systolic blood pressure of 100 mm Hg, when evaluated together with the SI, can be very concerning. This patient has a SI of 1 and at very high risk of decompensation in the peri-intubation period. These patients are at risk from any myocardial depression or vasodilation and should be started on in-line continuous vasopressors before intubation rather than relying on a bolus-dose vasopressor for rescue *after* decompensation.

3. **Augment ventricular performance:** After fluid resuscitation and vasopressors, the next principle is to determine whether there is any left ventricular or RV dysfunction that will decompensate with induction and PPV. Ventricular contractility that remains poor despite a vasopressor such as norepinephrine may require augmentation with an inotrope such as dobutamine or milrinone. In some instances (eg, restrictive physiology), the left ventricle may need afterload reduction and inotropic support rather than vasopressors.
4. **Mitigate effect of the induction agent:** All induction agents used for RSI have unfavorable hemodynamic consequences. These need to be balanced with optimizing intubating conditions for the patient to maximize the chances of first-pass success. At the doses required for RSI, propofol and midazolam result in venodilation, reducing both preload and blood pressure. Etomidate is considered a hemodynamically neutral drug, but recent evidence shows that etomidate reduces arterial elastance, which can cause hypotension. Ketamine has indirect sympathomimetic effects, however, is a direct myocardial depressant. Where one patient may respond to the sympathomimetic effect, another may get predominantly myocardial depression. Recent observational data have shown that ketamine was associated with more postintubation hypotension than etomidate, even when controlling for confounders and propensity matching. Induction agent choice will influence the choices made in steps 2 and 3 above,

and vice versa. Regardless of the induction agent used, a reduced dose should be used in patients with hemodynamic instability.

5. **Protect the right ventricle:** Patients with RV failure should have an RV-focused resuscitation and intubation. The "RV spiral of death" involves decreased RV systolic function leading to RV pressure/volume overload that decreases left ventricular filling, reducing cardiac output and worsening hypotension, which may then reduce RV function further. Intubation is often the final insult that tips the RV over the edge because of the increase in pulmonary vascular resistance that results from any atelectasis, ventilation/perfusion mismatch, hypoxemia, and hypercapnia that comes with apnea. Additionally, the increase in RV afterload from PPV can be very deleterious and result in postintubation hypotension or even cardiac arrest. Patients with RV failure may ultimately need pulmonary vasodilators to reduce RV afterload. In the ED, the key step is to recognize at-risk patients (eg, obstructive shock from a large pulmonary embolus) and initiate norepinephrine to increase mean arterial pressure, maintain coronary perfusion pressure, and RV contractility.

Complicating Factor of Acidosis

Metabolic derangements have widespread, varying, and complex effects on the respiratory and cardiovascular systems. Metabolic acidosis is the most troublesome of these derangements. Although mild metabolic acidosis can increase cardiac output modestly, it does so at the cost of increased myocardial oxygen demand and higher propensity for dysrhythmias. Severe metabolic acidosis results in myocardial depression. Blunting of myocardial response to circulating catecholamines is also an important factor. Catecholamine release in response to metabolic acidosis results in arterioconstriction, which again can lead to tachycardia, shortened filling time, and dysrhythmias.

When patients with severe metabolic acidosis have maximized their alveolar ventilation to maintain a pH barely compatible with life, the RSI-induced apnea can often be the tipping point into cardiac arrest as the $PaCO_2$ can rise rapidly and result in a plummeting pH. Before RSI is performed in

these patients, one must treat the underlying etiology for the metabolic acidosis as best as possible, feel confident that the patient can tolerate a drop in pH, and ensure that the patient's current alveolar ventilation can be matched with mechanical ventilation.

Who Should Be Intubated Awake?

Just as with hypoxemia, some patients have hemodynamics or acidemia that are so fragile and cannot be adequately attenuated that the only safe path to intubation for them is an awake intubation approach. This avoids the hemodynamic effects and alveolar ventilation effects associated with induction and neuromuscular blockade. Additionally, awake intubation permits a more gradual transition to PPV. In these cases, one must sacrifice the safety of first-attempt success with laryngoscopy for the cardiopulmonary safety associated with spontaneous ventilation.

TIPS AND PEARLS

- Patients should be assessed for the physiologically difficult airway during the preintubation evaluation, and mitigation strategies must be incorporated into the preintubation planning.
- The physiologically difficult airway can be thought about in two large buckets, the dangers of rapid desaturation and dangers of cardiovascular collapse, as well as factors that make the previous two more likely such as RV failure or severe metabolic acidosis.
- Factors associated with rapid desaturation include those that reduce the size of the FRC, limit denitrogenation, increase right-to-left shunt physiology, or increase peripheral oxygen consumption.
- Preoxygenation should be meticulously performed with the intent of complete denitrogenation, recruiting any available airspace, and reducing ventilation/perfusion mismatch. In patients that are refractory to preoxygenation, an awake approach should be strongly considered to maintain spontaneous ventilation.
- Cardiovascular collapse is often difficult to predict and prevent, and factors associated with cardiovascular collapse include those that

increase vasodilation and those that reduce cardiac output. A stepwise progression involving fluid resuscitation, vasopressor and inotrope support, and RV function support is required to minimize the risk of cardiovascular collapse in critically ill patients.

EVIDENCE

What is the evidence for the physiologically difficult airway?

Most studies on emergency airway management in the ED and ICU have shown a peri-intubation cardiac arrest rate between 1% and 4%.[1-3] When patients are hypoxemic or hypotensive prior to intubation (ie, the physiologically difficult airway), they have an adjusted odds of cardiac arrest almost 6 times that of patients that are neither hypoxemic nor hypotensive. When critically ill patients have a difficult airway, half have life-threatening complications.[3,4] However, the major increase in the risk to critically ill patients occurs with a second attempt.[3,5,6] What is most concerning is that despite increased first-attempt success rates in the published literature, complication rates remain alarmingly high. Sakles et al, Hypes et al, and De Jong et al all reported complication rates, mostly hypoxemia and hypotension, in patients with first-attempt success between 14% and 30%.[5-8] Russotto et al recently published the results of an observational study of intubations performed in critically ill patients across 29 countries and found that despite 95% of patients being successfully intubated in one or two attempts, half of the patients still experienced life-threatening complications.[4] Pacheco et al found that the presence of either anatomically or physiologically difficult airway characteristics decreased the first-attempt success *without* a complication by 10% (92% to 82%), and an additional 12% (82% to 70%) when both were present.[9] The adjusted odds ratio for first-attempt success without a complication was nearly the same when either was present (0.37 with anatomically difficult airway characteristics present, 0.36 with physiologically difficult airway characteristics present), and was only 0.19 when both were present. Overall, the data in the published literature support the physiologically difficult airway as a distinct source of danger to patients that requires careful

assessment and planning to the same degree as anticipated difficult laryngoscopy.

What are the risk factors for desaturation?

McKown et al evaluated patients enrolled in randomized clinical trials to determine independent risk factors for desaturation.[10] They identified the following independent risk factors: hypoxemic respiratory failure as the indication for intubation (OR 2.70), lower oxygen saturation at induction (OR 0.92 per 1% increase [above 95%]), younger age (OR 0.97 per 1 year increase), higher body mass index (OR 1.03 per 1 kg/m^2 [above 23 kg]), race (OR 4.58 for white vs black), and operator experience (OR 2.83 if <100 intubations).

What are the risk factors for hypotension?

Elevated SI has been shown consistently as a specific, yet insensitive, indicator of postintubation hypotension.[10-16] Three recent studies have shown that independent predictors of cardiovascular collapse include older age, hypotension or shock prior to intubation, intubation for respiratory failure, and higher APACHE scores prior to intubation.[15,17-19] In other words, sick patients with respiratory failure requiring intubation are at very high risk of *both* desaturation and cardiovascular collapse.

What is the evidence for advanced methods of preoxygenation?

Interpreting the evidence for preoxygenation is challenging. First, the PreVent trial showed that mask ventilation after induction but before laryngoscopy reduces severe hypoxemia rates from 23% to 11%. The INTUBE study that demonstrated a nearly 50% complication rate showed that 63% of patients were preoxygenated with bag-valve-mask ventilation. Compared to bag-valve-mask, preoxygenation with NIPPV in hypoxemic patients resulted in fewer desaturation events.[20] Vourc'h et al studied HFNO and reported that the rate of difficult intubation was 1.6% in the HFNO group and 7.1% in the facemask group, although it did not reach statistical significance.[22] Studies commonly do not evaluate apnea duration, but rather success rates as the surrogate, and are plagued with significant heterogeneity in definition and patient population. Yet, HFNO appears to be generally at least as good as facemask preoxygenation[22-25] for success rates,

but has the added benefit of remaining in place to provide apneic oxygenation and has shown that compared to facemask, it prevents desaturation, prolongs safe apnea time, and limits the depth of desaturation.[21-23,25-31] Miguel-Montanes et al found that HFNO is an independent predictor of preventing desaturation <80% (adjusted odds ratio [aOR] 0.14).[27] In the patients with the most severe hypoxemia undergoing RSI, NIPPV may provide the best preoxygenation.[24,25,31] However, HFNO can remain in place for apneic oxygenation and may provide some benefit. In a recent study, NIPPV had fewer desaturations, but none of the HFNO patients desaturated to <70% although 13% of patients preoxygenated with NIPPV desaturated to <70%.[22]

What is the evidence for resuscitation?

Jaber et al found that resuscitation, when included in an intubation bundle, significantly decreased complications in the ICU.[32] However, replication has proved elusive. A randomized controlled trial of patients without hypotension that required intubation, a 500-mL crystalloid bolus did not decrease the chances of hemodynamic collapse.[33] A randomized controlled trial of fluid *optimization* prior to induction in an operating room did not show a difference in outcomes either, and one-third of the patients were on vasopressors within 15 minutes of induction regardless of goal-directed optimization.[34] In trauma patients however, a preintubation blood product-based resuscitation reduced the incidence of hypotension, cardiac arrest, and mortality in injured combat troops.[35]

What is the evidence for induction agents?

A recent study showed that hypotension from etomidate may be mediated through a reduced arterial elastance, causing arterial dilation after induction.[36] Recent observational studies using the National Emergency Airway Registry (NEAR) database showed that ketamine was associated with a higher incidence of hypotension compared to etomidate, even after propensity matching and correcting for confounders,[37,38] a finding that was the opposite of a similar study in Japan.[39] A recent study in the ICU showed that etomidate and ketamine had similar outcomes, and both appeared to be worse than propofol as the sedative.[40,41]

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CHAPTER 4

Identification of the Failed Airway

Calvin A. Brown III

INTRODUCTION

A failed airway exists when a method of intubation is unsuccessful and gas exchange is failing in patients who cannot do so on their own. A failed airway scenario occurs when a provider has embarked on a certain course of airway management (eg, rapid sequence intubation [RSI]) and has recognized that intubation by that method is not going to succeed, requiring the immediate initiation of a rescue sequence. Certainly, in retrospect, a failed airway can be called a difficult airway because it has proven to be difficult or impossible to intubate, but the terms “failed airway” and “difficult airway” must be kept distinct because they represent different situations, invoke different actions, and arise at different points in the airway management timeline.

In contrast to difficult airway management, for which the goal is placement of a definitive airway, failed airway management focuses on ensuring adequate oxygenation by any means. The failed airway algorithm and its management strategies are described in detail in Chapter 5.

THE FAILED AIRWAY

A failed airway exists when any of the following conditions are met:

1. Failure to maintain acceptable oxygen saturation during or after any missed laryngoscopic attempt (CICO) *or*
2. Two failed attempts at orotracheal intubation by an experienced intubator, even when oxygen saturation can be maintained *or*

3. The single “best attempt” at intubation is unsuccessful in the “Forced to Act” situation (see Chapter 5).

Clinically, the failed airway presents itself in two ways, dictating the urgency created by the situation:

1. **Can’t** *Intubate*, **Can’t** *Oxygenate:* There is insufficient time to evaluate or attempt a series of rescue options. Rescue oxygenation cannot be accomplished by bag-mask ventilation (BMV) or extraglottic device (EGD) and the airway needs to be secured immediately.
2. **Can’t** *Intubate*, **Can** *Oxygenate:* There is time to evaluate and execute various options because the patient can be oxygenated by BMV or an EGD.

One way of thinking about this is that the difficult airway is something one anticipates and plans for whereas the failed airway is something one experiences (particularly if one did not assess for, and anticipate, a difficulty airway). However, the incidence of overall intubation failure is quite low, that is, <1%. Intubation failure occurs when the patient can be neither intubated nor oxygenated. It also exists when multiple attempts at placement of a cuffed tube in the trachea have been unsuccessful, yet the patient can be oxygenated by an alternative method, such as by BMV or using an EGD. The incidence of the “*can’t* intubate, *can’t* oxygenate” (CICO) situation in preselected operating room intubations is rare, estimated to occur once in 5000 to 20 000 intubations. The true incidence is unknown in emergency intubations, but it is likely substantially more common, given patient acuity, lack of preselection, and a higher rate of difficult airway markers. Rescue cricothyrotomy most often happens in the setting of a *can’t* oxygenate failed airway, but its incidence has declined with the advent of video laryngoscopy (VL) and various rescue devices. Based on a large registry data of adult intubations, rescue surgical airways occur in 0.3% to 0.5% of all airway encounters in the emergency department (ED). Furthermore, recognizing the failed airway promptly allows use of the failed airway algorithm to guide selection of a rescue approach.

Some argue that the term “failed” has too negative a connotation and emergency airway providers have an intrinsic desire to avoid failure at all costs. It is thought that labeling an airway as *failed* may prevent the intubator from letting go and taking necessary corrective actions to save the situation. A failed airway should *not* be understood to mean the provider has “failed the patient” or is him/herself a failure. In contrast, the idea of the failed airway is meant to be distinct from airway difficulty or any single missed intubation attempt. It should invoke a stark understanding that the current approach is not going to work and a rescue strategy, one that focuses on gas exchange and not definitive airway placement, needs to be prioritized. Without being able to recognize and call an airway as having “failed” one runs the risk of remaining on the current unsuccessful path of foolishly attempting intubation when a shift to providing rescue oxygenation (via EGD, BMV, or cricothyrotomy) is required.

The most important way to avoid airway management failure is to identify in advance those patients for whom difficulty can be anticipated with intubation, BMV, insertion of an EGD, or cricothyrotomy. In the “Forced to Act” scenario, airway difficulty is apparent, but the clinical conditions (eg, combative, hypoxic, rapidly deteriorating patient) force the operator’s hand, requiring administration of RSI drugs to create the best possible circumstances for tracheal intubation, with immediate progression to failed airway management if that one best attempt is not successful (see Chapter 5).

EVIDENCE

What is the incidence of a can’t intubate and can’t oxygenate (CICO) failed airway in the emergency department?

The exact incidence of airway failure in the ED is unknown. However, a reasonable surrogate marker is the rate of cricothyrotomy, as most patients with a CICO failed airway require surgical access. In a recent analysis of 4500 trauma intubations from the National Emergency Airway Registry (NEAR), 31 of 4499 patients needed a surgical airway (0.7%, 95% CI: 0.5% to 1.0%); however, 7 of 31 surgical airways (23%) were done on first attempt.[1] The “rescue” surgical airway rate (ie, a cricothyrotomy performed after another method was attempted) was observed to be 24 out of 4499, or

0.53%. In a cohort of approximately 15 800 medical intubations, 18 (0.12%) surgical airways were recorded in the registry.[2] No pediatric surgical airways were observed.

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CHAPTER 5

The Emergency Airway Algorithms

Calvin A. Brown III

APPROACH TO THE AIRWAY

This chapter presents and discusses the emergency airway algorithms, which we have used, taught, and refined for nearly 25 years. These algorithms are intended to reduce error and improve the pace and quality of decision-making for an event that is uncommonly encountered by most practitioners, and often disrupts attempts at sound and orderly clinical management.

When we first set out to try to codify the cognitive aspects of emergency airway management, we were both liberated and impaired by the complete lack of any such algorithms to guide us. In developing The Difficult Airway Course: Emergency, The Difficult Airway Course: Anesthesia, The Difficult Airway Course: Critical Care, and The Difficult Airway Course: EMS, and in applying, successively, each iteration of the emergency airway algorithms to tens of thousands of real and simulated cases involving thousands of providers, we felt guided by both our continuous learning about optimal airway management and the empirical application of these principles. They are based on both the best evidence available and consensus of the most reputable experts in the field of emergency airway management. These algorithms, or adaptations of them, now appear in many of the major emergency medicine textbooks and online references. They are used in airway courses, for residency training, and in didactic teaching sessions, both for in-hospital and out-of-hospital providers. They have stood the test of time and have benefited from constant updates.

The adoption of video laryngoscopy (VL) as the emergency airway manager's principal tool has caused us to rethink concepts related to the definition and management of the "difficult airway" (see Chapters 2 and 3). This sixth edition includes the foundational concepts of our proven algorithmic approach to airway management augmented by a new cardiac arrest airway algorithm and the integration of flexible intubation methods, VL, and a focus on, especially during rapid sequence intubation (RSI), "physiologic optimization". This step is designed to recognize and address patients with impaired oxygenation or poor cardiovascular reserve and, by doing so, create safer intubating conditions. Although we describe this as a discreet step during RSI (see Chapter 20), optimization of oxygenation and hemodynamics should occur, if time and resources allow, during *all* emergency intubations. Extraglottic devices (EGDs) continue to be refined, are easy to use, can facilitate tracheal tube placement, and most offer the benefits of gastric decompression. Surgical airway management, although still an essential skill, moves from uncommon to rare as the sophistication of first-line devices, rescue tools, and safe intubation practices increases.

Together, as before, these algorithms comprise a fundamental, *reproducible* approach to the emergency airway. The purpose is not to provide a "cookbook" or a rigidly followed blueprint which one could universally and mindlessly apply, but rather to describe a reproducible set of decisions and actions to enhance performance and maximize the opportunities for success, even in difficult or challenging cases.

The specialized algorithms all build from concepts found in the universal emergency airway algorithm, which describes the priority of the key decisions: determining whether the patient represents a cardiac arrest airway, an anatomically or physiologically difficult airway, or a failed airway. In addition, we recommend achieving physiologic optimization as an essential step in all airway management, considering the patient's condition as well as the time and resources available. The decision to intubate is discussed in Chapter 1, and the entry point into the emergency airway algorithms is immediately after the decision to intubate has been made.

The "forced to act" option, part of the difficult airway algorithm, is maintained for this update. There are clinical circumstances in which it is essential to use neuromuscular blocking agents (NMBAs) even in the face

of obvious airway difficulty, simply because the need for intubation is immediate and there is little time to plan any other approach. The operator who is *forced to act* uses an induction agent and an NMBA to create the best possible conditions for intubation—in other words, to facilitate the one best chance to secure the airway and for successful rescue should the primary method fail. The forced to act option implies a time-critical need for intubation because of a dynamically changing airway or rapidly deteriorating patient. An example of this might be the morbidly obese difficult airway patient who prematurely self-extubates in the intensive care unit (ICU) and is immediately agitated, hypoxic, and deteriorating. Although the patient's habitus and airway characteristics normally would argue against the use of RSI, the need to secure the airway within a few minutes and the patient's critical deterioration mandate immediate action. By giving an NMBA and induction agent, the operator can optimize conditions for VL, with a plan to either insert a laryngeal mask airway (LMA) or perform a surgical airway if unsuccessful. In rare cases, the primary method may be a surgical airway.

The algorithms are intended as guidelines for management of the emergency airway, regardless of the locus of care (emergency department [ED], inpatient unit, operating room, ICU, and out-of-hospital). The goal is to simplify some of the complexities of emergency airway management by defining distinct categories of airway problems. For example, we single out those patients who are agonal or coding and manage them using a distinct pathway, the cardiac arrest airway algorithm. Similarly, a patient with an anatomically difficult airway must be identified and managed according to sound principles.

Significant anatomic distortion will impede effective laryngoscopy and tube placement and would be a relative contraindication to RSI. If it is anticipated that critical hypoxemia might occur before tracheal intubation is completed, then an awake intubation should be performed. An example of this might be a patient with Ludwig's angina who arrives with difficulty breathing, trismus, and upper airway obstruction. In this case, traditional orotracheal intubation, even with VL, is anticipated to be difficult or impossible and rendering the patient apneic would likely create a failed airway scenario.

VL has mitigated many, but not all, of the hazards that challenging anatomy imposes on direct laryngoscopy. The threshold for using RSI, in the context of difficult anatomy, has appropriately gone down. However, this has been supplanted by an increasing awareness that deranged physiology can introduce as much risk to emergency airway management as challenging anatomy. For the sixth edition, we have updated the difficult airway algorithm so that compromised physiology is considered before final airway management plans are made.

In human factors analysis, failure to recognize a pattern is often a precursor to medical error. The algorithms aid in pattern recognition by guiding the provider to ask specific questions, such as “Is this airway difficult?” and “Is this a can’t intubate and can’t oxygenate (CICO) failed airway?” The answers to these questions group patients with certain characteristics together and each group has a defined series of actions. For example, in the case of a difficult airway, the difficult airway algorithm facilitates formulation of a distinct, but reproducible plan, which is individualized for that particular patient, yet lies within the overall approach that is predefined for all patients in this class, that is, those with difficult airways.

Algorithms are best thought of as a series of *key questions* and *critical actions*, with the answer to each question guiding the next critical action. The answers are always binary: “yes” or “no” to simplify and speed cognitive factor analysis. **Figures 5.1** and **5.2** provide an overview of the algorithms, and how they work together.

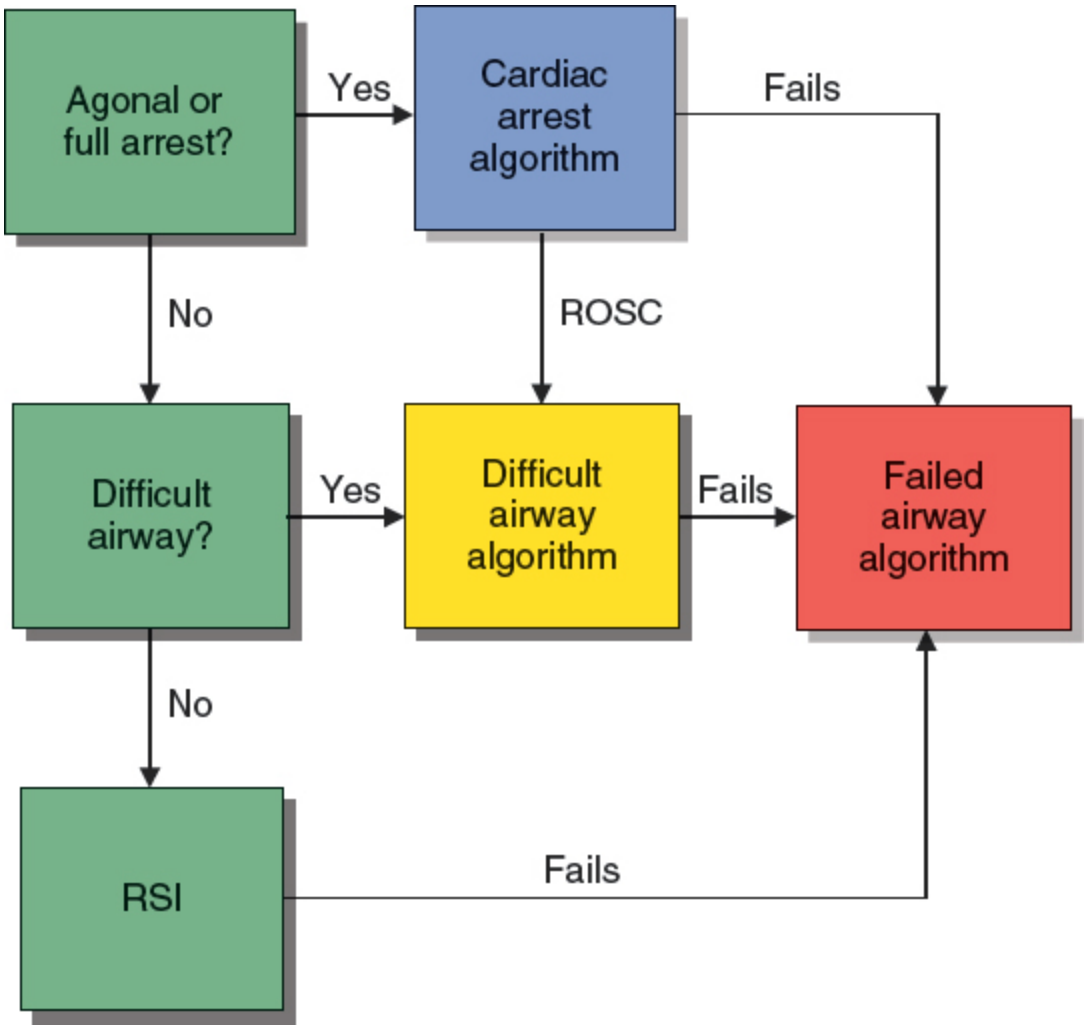

Figure 5.1: Universal emergency airway algorithm. This algorithm demonstrates how the emergency airway algorithms work together. For all algorithms, green represents the main algorithm, yellow is the difficult airway algorithm, blue is the crash airway algorithm, red is the failed airway algorithm, and orange represents an end point. (© 2022 The Difficult Airway Course: Emergency.)

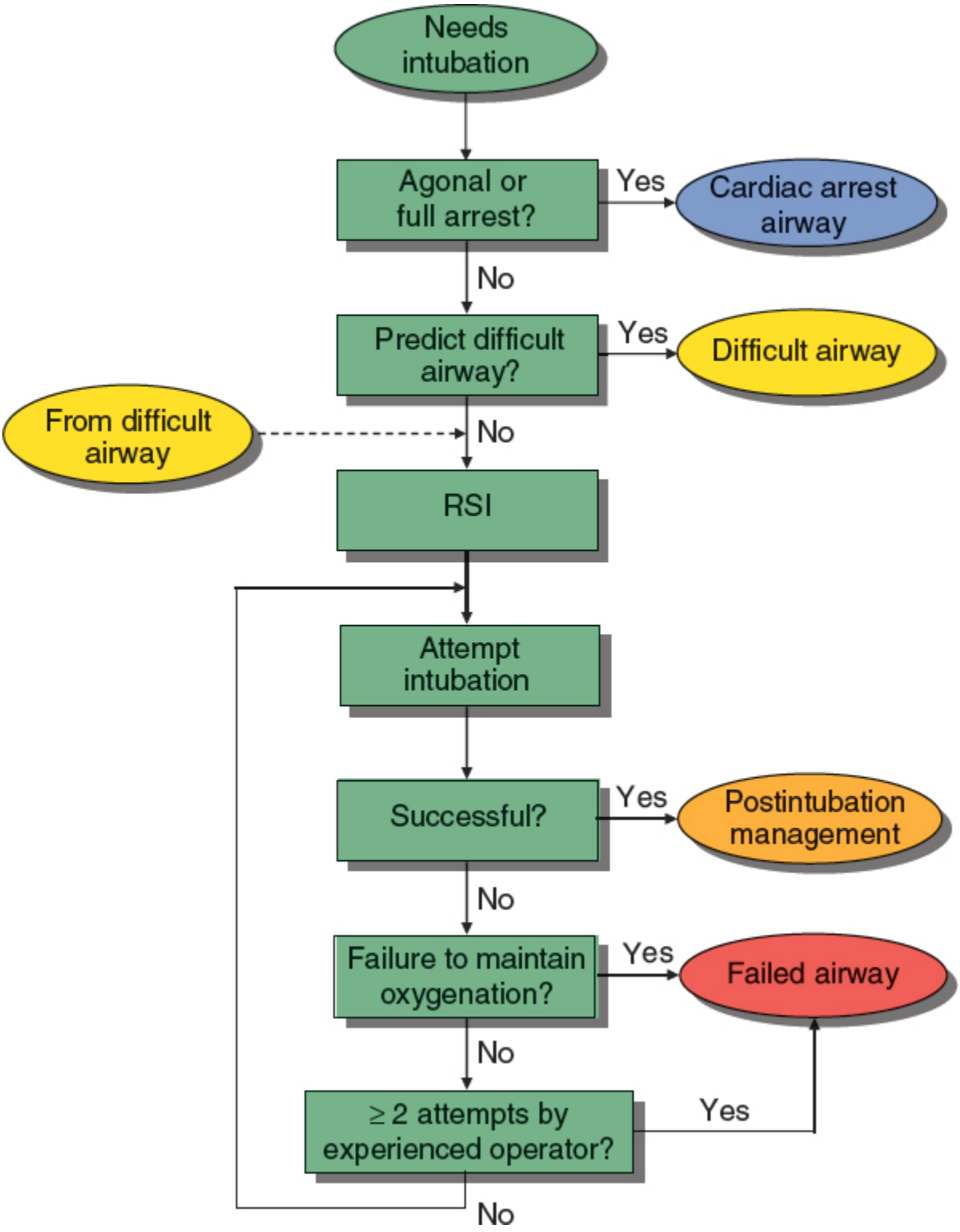

Figure 5.2: Main emergency airway management algorithm. See text for details. (© 2022 The Difficult Airway Course: Emergency.)

When a patient requires intubation, the first question is “Is this patient agonal or in arrest?” A patient that is agonal or in full arrest would qualify for cardiac arrest airway management, which has replaced the concept of the “crash airway” for this sixth edition. The crash airway was historically meant to describe patients who needed emergent intubation and were transitioning from critical illness to full respiratory or cardiac arrest. The opportunity to catch patients in this rapid transition is rare. In practice, patients present either critically ill, for whom physiologic optimization is the priority along with airway management (see Chapter 20), or cardiorespiratory arrest for whom airway management typically involves bag-mask-ventilation (BMV) or placement of an EGD followed by definitive airway management if there is return of circulation. If the answer is “yes,” the patient should be managed using the cardiac arrest airway management algorithm (**Fig. 5.3**) with BMV or EGD placement during active cardiopulmonary resuscitation (CPR). Plans for intubation can be made if the patient is successfully resuscitated or, if still in arrest, the provider decides a definitive airway is required because of vomit, a prolonged code, or need for procedures that mandate a tracheal tube be placed (eg, transesophageal echocardiogram [TEE]). If the answer is “no,” the next question is “Is this a difficult airway?” (see Chapters 2 and 3). If the answer is “yes,” the patient is managed as a difficult airway (**Fig. 5.4**). If the answer is “no,” then RSI is recommended, as described on the main algorithm (Fig. 5.2). Regardless of the algorithm used initially, if airway failure occurs, the failed airway algorithm is immediately invoked (**Fig. 5.5**). The working definition of the failed airway is crucial and is explained in much more detail in the following sections. It has been our experience that airway management errors occur because the provider either does not recognize the situation (eg, failed airway), or does not know what actions to take.

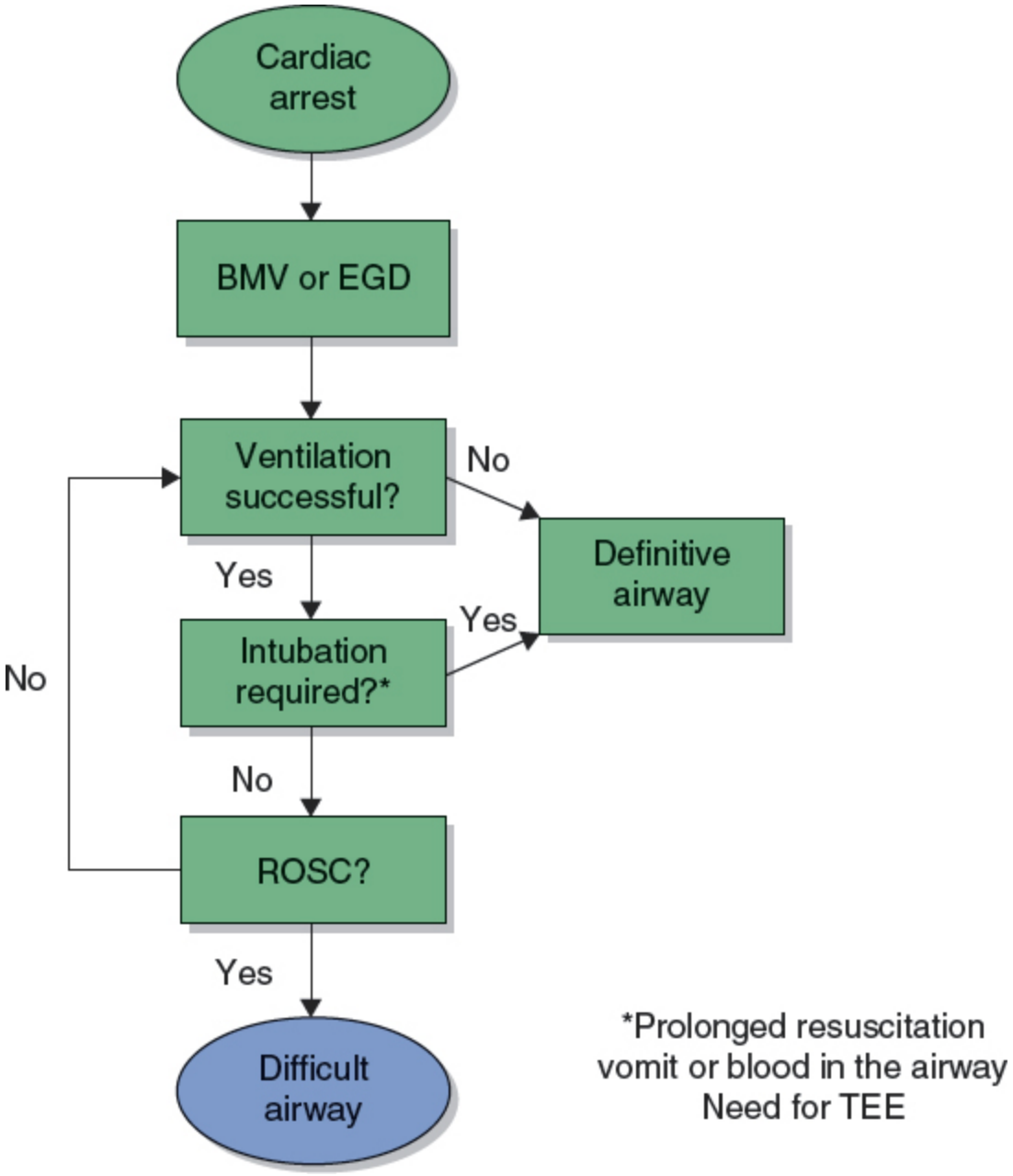

Figure 5.3: Cardiac arrest airway algorithm. *Prolonged code, vomiting or bleeding in the airway, transesophageal echocardiogram (TEE). BMV, bag-mask-ventilation; EGD, extraglottic device; ROSC, return of spontaneous circulation. (© 2022 The Difficult Airway Course: Emergency.)

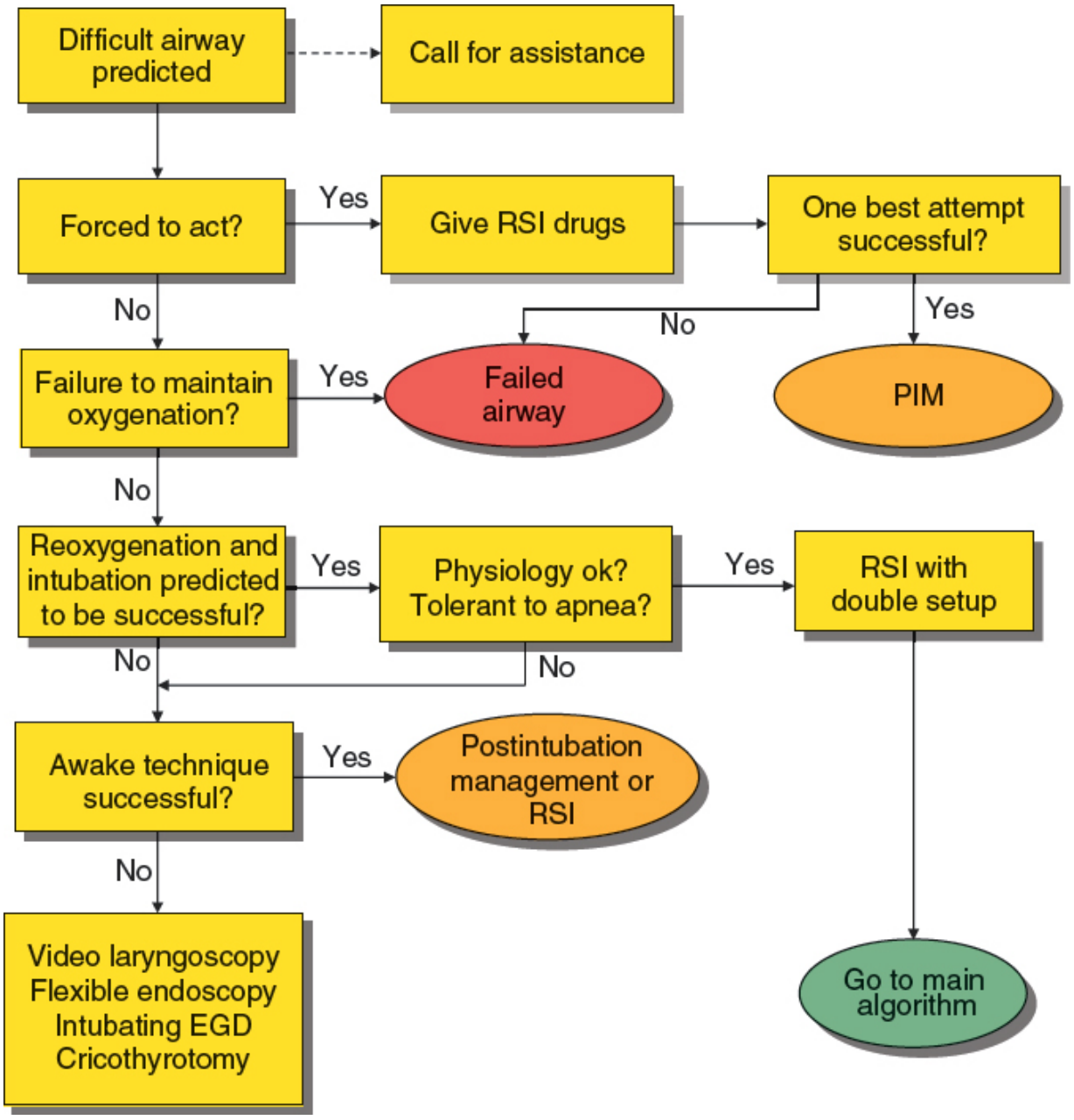

Figure 5.4: Difficult airway algorithm. See text for details. EGD, extraglottic device. PIM, postintubation management. RSI, rapid sequence intubation. (© 2022 The Difficult Airway Course: Emergency.)

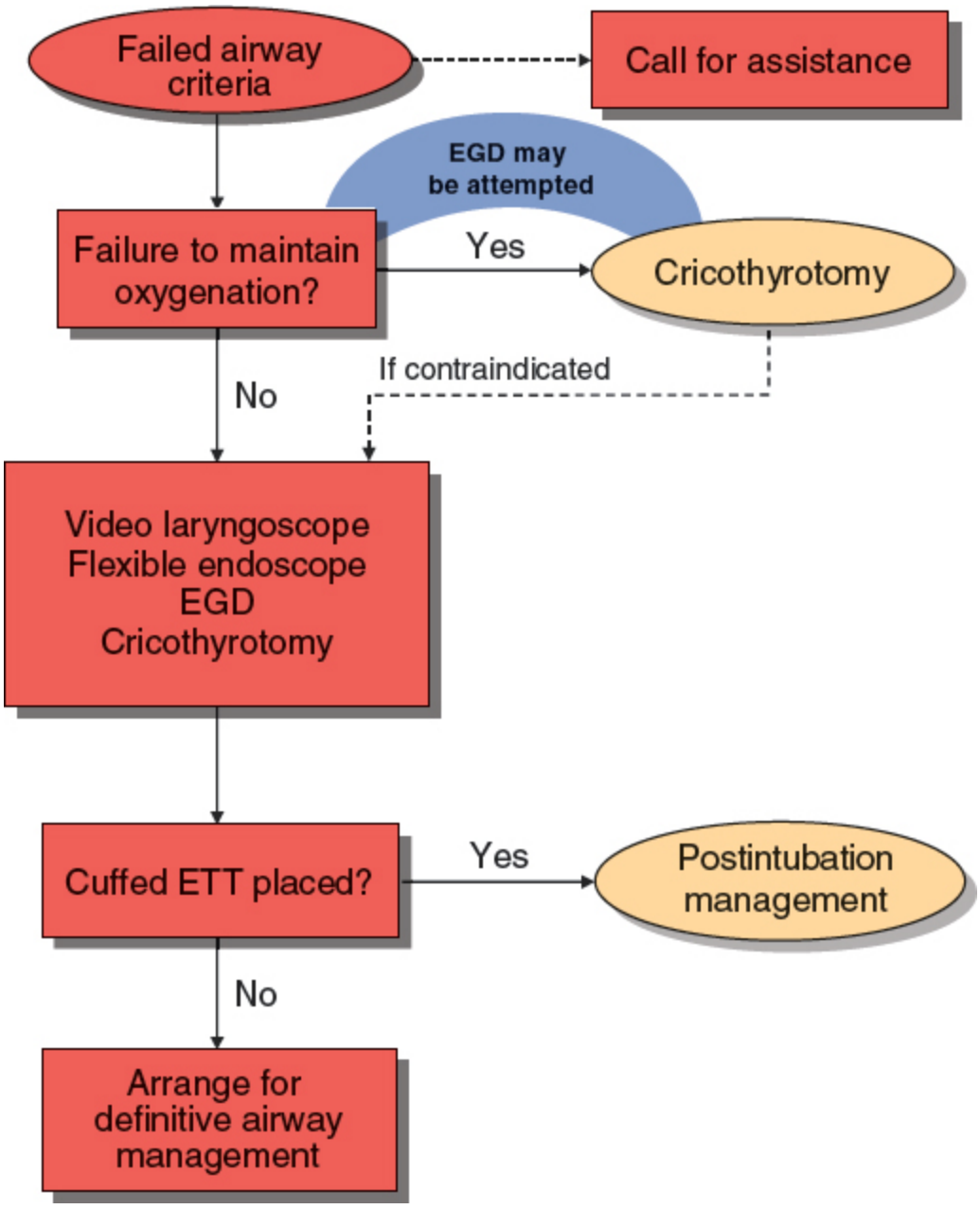

Figure 5.5: Failed airway algorithm. See text for details. EGD, extraglottic device; ETT, endotracheal tube. (© 2022 The Difficult Airway Course: Emergency.)

THE MAIN AIRWAY ALGORITHM

The main emergency airway algorithm is shown in Figure 5.2. It begins after the decision to intubate and ends when the airway is secured, whether intubation is achieved directly or through one of the other algorithms. The

algorithm is navigated by following defined steps with decisions driven by the answers to a series of key questions as follows.

Key question 1: Is the patient agonal or in full cardiorespiratory arrest?

If the patient is agonal or in full arrest for whom CPR is either in progress or about to begin, then the patient is defined as a cardiac arrest airway. These patients are often relaxed, unlikely to resist invasive airway maneuvers, and managed in a manner appropriate for their extreme condition. If a cardiac arrest airway is identified, exit the main algorithm and enter the cardiac arrest airway algorithm (Fig. 5.3). Otherwise, continue with the main algorithm.

Key question 2: Is this a difficult airway?

If the airway is not a cardiac arrest airway, the next task is to determine whether it is a difficult airway. An airway may be difficult because of altered anatomy, or severely deranged physiology. With the former, anatomic challenges make visualization of the airway challenging and may preclude successful tracheal intubation. With the latter, peri-intubation adverse events may occur, not because of inability to place a tracheal tube, but because myocardial depression, hypotension, and positive pressure ventilation can result in circulatory collapse. Anatomic difficulty encompasses difficult DL or VL intubation, difficult BMV, difficult EGD use, and difficult cricothyrotoimy. Chapter 2 outlines the assessment of the patient for a potentially difficult anatomic airway using the various mnemonics (LEMON, ROMAN, RODS, and SMART) corresponding to these dimensions of difficulty. Difficult VL is rare if there is enough mouth opening to allow insertion of the device. Although some predictive parameters have started to become identified, a validated set of patient characteristics is yet to be defined. Identification of the difficult physiologic airway is discussed in Chapter 3. The elements are recalled by the CRASH mnemonic. It is understood that virtually all emergency intubations are difficult to some extent. However, the evaluation of the patient for attributes that predict difficult airway management is extremely important. If the patient represents a potential difficult airway situation, then he or she is managed using the difficult airway algorithm (Fig. 5.4), and one would exit the main algorithm. The LEMON assessment for difficult laryngoscopy and

intubation and the ROMAN assessment for difficult reoxygenation with BMV or an EGD are the main drivers of predictable anatomic airway challenges; however, an evaluation of the other difficulties (cricothyrotomy and EGD) is critical at this point as well. If the airway is not identified as particularly difficult, continue with the main algorithm to the next step, which is to perform RSI.

Critical Action: Perform RSI

In the absence of an identified cardiac arrest or difficult airway, RSI is the method of choice for emergency intubation. RSI is described in detail in Chapter 20 and affords the best opportunity for success with the least likelihood of adverse outcome of any possible airway management method, when applied to appropriately selected patients. This step assumes that the appropriate sequence of RSI (the seven Ps) will be followed. If the patient is hemodynamically unstable and the need for intubation is *not* immediate, an effort to optimize patient physiology should occur as plans for intubation are finalized and drugs are drawn up. During RSI, intubation is attempted. According to the standard nomenclature of the National Emergency Airway Registry (NEAR), a multicenter study of emergency intubations, *an attempt is defined as activities occurring during a single continuous laryngoscopy maneuver, beginning when the laryngoscope is inserted into the patient's mouth, and ending when the laryngoscope is removed, regardless of whether a tracheal tube is actually inserted into the patient.* In other words, if several attempts are made to pass an endotracheal tube (ETT) through the glottis during the course of a single laryngoscopy, these aggregate efforts count as one attempt. If the glottis is not visualized and no attempt is made to insert a tube, the laryngoscopy is still counted as one attempt. These distinctions are important because of the definition of the failed airway that follows.

Key question 3: Was intubation successful?

If the first oral intubation attempt is successful, the patient is intubated, postintubation management (PIM) is initiated, and the algorithm terminates. If the intubation attempt is not successful, continue with the main pathway.

Key question 4: Can the patient's oxygenation be maintained?

When the first attempt at intubation is unsuccessful, it often is possible and appropriate to attempt a second laryngoscopy without interposed BMV, as oxygen saturations often remain acceptable for an extended period following proper preoxygenation. Desaturation can be delayed even further with apneic oxygenation, the continuous delivery of supplemental oxygen by nasal cannula during RSI. In general, active BMV is not necessary until the oxygen saturation falls below 94%. Because peripheral oxygen saturation readings often lag behind actual oxyhemoglobin levels and the rate at which hemoglobin releases its oxygen stores accelerates at this point, it is appropriate to abort laryngoscopic attempts when oxygen saturations fall below 94% and begin rescue mask ventilation. This approach underscores the importance of assessing the likelihood of successful reoxygenation by BMV or EGD (ROMAN, see Chapter 2) before beginning the intubation sequence. In most cases, especially when neuromuscular blockade has been used, BMV will provide adequate ventilation and oxygenation for the patient. If BMV is not capable of maintaining the oxygen saturation at or above 94%, a better technique including oral and nasal airways, use of the two-person two-handed technique with a thenar grip, and optimal patient positioning, will usually result in effective ventilation (see Chapter 12). If reoxygenation efforts fail and oxygen saturations keep dropping despite the optimal technique, the airway is considered a CICO failed airway, and one must exit the main algorithm immediately and initiate the failed airway algorithm (Fig. 5.5). This is the most recognized definition of a failed airway. In a CICO failed airway, rescue strategies are begun immediately to prevent further desaturation and its sequelae, anoxic injury, or cardiac arrest. Recognition of the failed airway is crucial because delays caused by persistent, futile attempts at intubation will waste critical seconds or minutes and may sharply reduce the time remaining for a rescue technique to be successful before brain injury ensues.

Key question 5: Have two attempts at orotracheal intubation been made by an experienced operator?

In addition to CICO, there are two additional definitions of airway failure that need to be considered: (i) “two missed attempts by an experienced operator”; (ii) a missed *single best attempt* in the context of a “forced to

act" scenario (described in the difficult airway algorithm section). If two separate attempts at orotracheal intubation by an experienced operator using the best available device have been unsuccessful, then the airway is also defined as a failed airway, despite the ability to adequately oxygenate the patient using a bag and mask. Data from the NEAR have shown that the majority (>95%) of all ED intubations are successful within two attempts. If an experienced operator has used the best available method of laryngoscopy, typically VL, for two attempts without success, the incremental benefit of a third try does not justify the risk of airway trauma, swelling, desaturation, and clinical deterioration that occurs with successive attempts. As a general rule, the operator should recognize the failed airway and manage it as such using the failed airway algorithm. If the first attempt was unsuccessful, but BMV is successful, then it is appropriate to attempt orotracheal intubation again, provided the oxygen saturation is maintained and the operator can identify an element of the laryngoscopy that can be improved and likely to lead to success (eg, use of a different device). Similarly, if the initial attempt was made by an inexperienced operator, such as a trainee, and the patient is adequately oxygenated, then it is appropriate to reattempt oral intubation until two attempts by the most experienced operator have been unsuccessful. If available, at least one of those attempts should be made with a video laryngoscope, and if the initial attempt failed using conventional laryngoscopy, we recommend switching to a video laryngoscope for the second attempt. This is not an absolute rule, however, and additional attempts at laryngoscopy may be appropriate before declaring a failed airway. This most often occurs when the operator identifies a particular strategy for success (eg, better control of the epiglottis by using a larger laryngoscope blade, switching to a video laryngoscope) during the second unsuccessful attempt. Similarly, it is possible that an *experienced* operator will recognize on the *very first attempt* that further attempts at orotracheal intubation will not be successful. In such cases, provided that the patient has been optimally positioned for intubation, good relaxation has been achieved, and it is the operator's judgment that further attempts at laryngoscopy would be futile, the airway should be immediately regarded as a failed airway, and the failed airway algorithm initiated. Thus, it is not essential to always make two laryngoscopic attempts before labeling an airway as failed, but two failed attempts by an experienced

operator with optimal adjuncts should be considered a failed airway, unless the laryngoscopist identifies a particular problem and solution, justifying one more attempt.

THE CARDIAC ARREST AIRWAY ALGORITHM

Entering the cardiac arrest airway algorithm (Fig. 5.3) indicates that one has identified an agonal or coding patient with an immediate need for oxygenation and ventilation. In this algorithm, definitive airway management (ie, placement of a cuffed tube in the trachea) is superseded by overall resuscitation management and quality CPR. The goal of airway management is to provide oxygenation to allow return of cardiac activity and spontaneous circulation. High-quality BMV or the use of an EGD is the initial step in cardiac arrest airway management.

Key question 1: Is the patient agonal or pulseless?

Confirm the patient is either agonal, on the verge of arrest, or in full cardiopulmonary arrest. This will be evident by rapid bedside assessment of respirations and peripheral pulses.

Critical Action: Perform BMV or place an EGD

To align with advanced cardiac life support (ACLS) recommendations, initial airway management involves ventilation and oxygenation by either a bag and mask device or an EGD. The EGD used is not defined here and will be based primarily on availability and clinician comfort. An EGD that can facilitate either blind (eg, LMA Fastrach) or guided tracheal intubation via flexible endoscope (eg, i-gel, AirQ) is preferred.

Key question 2: Does ventilation seem to be successful?

This will be determined by a combination of the waveform capnography, ease of bagging, and visible chest excursion. Oxygen saturations cannot be relied upon during cardiac arrest. With BMV, if ventilation is inadequate or unsuccessful, ensure that oral and nasal airways are in place and a two-person, two-handed thenar grip technique is being used (see Chapter 12). If BMV is still unsuccessful, then insert an EGD and reattempt ventilation. Alternatively, an EGD can be placed as the first airway maneuver.

Critical Action: Attempt at Definitive Airway

If both BMV and EGD are deemed to be failing (ie, no capnogram trace, high resistance to bagging, no visible chest rise), then attempt definitive airway placement. This can typically be accomplished without the use of drugs. Most often, the initial attempt will be orotracheal intubation. If intubation fails, perform a cricothyrotomy. In rare circumstances, such as progressive upper airway edema, a cricothyrotomy may be the preferred first method for definitive airway placement if the clinician believes orotracheal intubation would be futile because of severe swelling. If definitive airway placement is successful, then proceed with ongoing code management.

Key question 3: Is there a need for intubation during the code?

Circumstances may arise during an active code that make tracheal intubation desirable or necessary. These include large volume emesis or active bleeding (for which airway protection against aspiration with a cuffed tracheal tube is required), a prolonged code, or the need for a specialized procedure such as a TEE.

Critical Action: Attempt at Definitive Airway

Attempt intubation as outlined in the previous step. If intubation is unsuccessful, perform a cricothyrotomy. If intubation is successful, proceed with ongoing code management.

Key question 4: Is there return of circulation?

A pulse check is performed after CPR and a round of code medications. If the patient remains pulseless, reevaluate ventilation via BMV or EGD and retrace your steps through the algorithm. This loop will continue until the code is either terminated or pulses return.

Critical Action: Move to Difficult Airway Algorithm

If circulation returns, one can move to the difficult airway algorithm to plan for definitive airway management. In the peri-arrest period, patients may be pressor-dependent and hemodynamically unstable. If this is the case, continue hemodynamic optimization (see Chapter 20) until the best

hemodynamic environment is obtained, followed by careful drug selection and RSI.

THE DIFFICULT AIRWAY ALGORITHM

Identification of the anatomically and physiologically difficult airway is discussed in detail in Chapters 2 and 3. This algorithm (Fig. 5.4) represents the clinical approach that should be used in the event of an identified potential difficult airway.

Critical Action: Call for Assistance

The "call for assistance" box is linked as a dotted line because this is an optional step, dependent on the clinical circumstances, skill of the airway manager, available equipment and resources, and availability of additional personnel.

Key question 1: Is the operator forced to act?

In some circumstances, although the airway is identified to be difficult, patient conditions force the operator to act immediately, before there is rapid deterioration of the patient into respiratory arrest. An example of this situation is given earlier in this chapter. Another example is a patient with rapidly progressive anaphylaxis from a contrast reaction while getting a computed tomography (CT) scan. The patient is anxious, agitated, and in severe distress. In such cases, there may not be time to obtain and administer epinephrine or antihistamines and reassess for improvement before total airway obstruction occurs. In such circumstances, dynamic airway deterioration is occurring so rapidly that a prompt decision to give RSI drugs and create circumstances for a *best single attempt* at tracheal intubation, whether by laryngoscopy or surgical airway, is preferable to medical management alone and hoping for immediate reversal as the patient progresses to complete airway obstruction, respiratory arrest, and death. Administration of RSI drugs will optimize the operator's ability to intubate, perform a surgical airway, place an EGD, or use a bag and mask to oxygenate the patient. The key is for the operator to make the *one* best attempt that, in the operator's judgment, is most likely to succeed. If the attempt is successful, then the operator proceeds to PIM. If that one attempt

is not successful, a failed airway is present, and the operator proceeds to the failed airway algorithm.

Key question 2: Are oxygen saturations dropping?

In the context of the difficult airway, *oxygen is time*. If preoxygenation efforts (see Chapter 20) result in stable, adequate oxygen saturations at or above 94%, then a careful assessment and a methodical, planned approach can be undertaken, even if significant preparation time is required. If oxygen saturations are dropping and cannot be stabilized, immediately move to the failed airway algorithm. This situation is equivalent to a "can't intubate (the identified difficult airway is a surrogate for can't intubate), can't oxygenate (adequate oxygen saturation cannot be maintained)" failed airway. Certain difficult airway patients will have chronic pulmonary disease, for example, and may not be able to reach an oxygen saturation of 93%, but can be kept stable and viable at, say, 89%. Additionally, a patient may have been considered difficult because of a cervical collar placed by emergency medical services (EMS) after an isolated head injury, but the suspicion for cervical spine injury is low and there are no other markers of airway difficulty. In this example, an experienced airway manager, armed with a video laryngoscope, may not consider this situation analogous to a "can't intubate" scenario. In other words, whether to call these cases failed airways is a matter of judgment considering both the degree of oxygen debt and the severity of predicted difficulty. If a decision is made to proceed down the difficult airway algorithm rather than switching to the failed airway algorithm, it is essential to be aware desaturation may occur rapidly during intubation attempts and a final judgment about the appropriateness of RSI versus an awake technique still needs to be made.

Key question 3: Should I use an NMBA on this patient?

Is rescue oxygenation using a bag and mask or EGD predicted to be successful? Is rapid desaturation anticipated? Is laryngoscopy predicted to be successful? Having a patient in the difficult airway algorithm does not obviate RSI. In fact, in most cases, RSI remains the best approach despite the presence of airway difficulty. This decision hinges, primarily, on the degree of predicted difficult laryngoscopy, the safe apnea time, and the likelihood of successful rescue reoxygenation should the patient desaturate.

There are three key factors combined into one composite “yes or no” question.

The first, and most important, factor is whether one predicts with confidence that gas exchange can be maintained by BMV or the use of an EGD if RSI drugs are administered rendering the patient paralyzed and apneic. This answer may already be known whether BMV has been required to maintain the patient’s oxygenation or whether the difficult airway evaluation did not identify difficulty for oxygenation using BMV or an EGD. Anticipating successful oxygenation using BMV or an EGD is an essential prerequisite for RSI, except in the “forced to act” situation described earlier. In some cases, it may be desirable to attempt a trial of BMV, but this approach does not reliably predict the ability to bag-mask ventilate the patient after paralysis. Second, what is the anticipated risk of critical hypoxemia caused by rapid desaturation before laryngoscopy can begin? After administration of RSI medications, the patient will become significantly hypopneic from the induction agent. This will occur well before full neuromuscular blockade is complete. As a result, exceptionally high-risk patients (eg, an obese patient with COVID-19 and hypoxemic respiratory failure) may dangerously desaturate before conditions exist to permit an intubation attempt. In these situations, even when laryngoscopy is expected to be straightforward, successful tube placement and reoxygenation may not occur before cardiac arrest ensues. If BMV or EGD use is anticipated to be successful and rapid desaturation risk is not high, then the next consideration is whether laryngoscopy and intubation is likely to be successful, despite the difficult airway attributes. Many patients with identified difficult airways undergo successful emergency intubation employing RSI, particularly when a video laryngoscope is used. So, if there is a reasonable likelihood of success with oral intubation, *despite predicting a difficult airway,* RSI may be undertaken. Remember, this is predicated on the fact that one has already judged that gas exchange (BMV or EGD) will be successful and oxygen saturations can be maintained long enough to permit a laryngoscopic attempt.

In these cases, RSI is performed using a “double setup,” in which the rescue plan (often cricothyrotomy) is clearly established, and the operator is prepared to move promptly to the rescue technique if intubation using RSI is not successful (failed airway). Given the high rate of difficult emergency

intubation, it is prudent to *always* prepare for airway failure, including the possibility of surgical rescue, even when intubation is expected to be straightforward. Therefore, when RSI is undertaken despite identification of difficult airway attributes, appropriate care during the technique and planning related to the particular difficulties present will result in success.

To reiterate these fundamental principles, if gas exchange employing BMV or EGD is not confidently assured of success, the risk of critical desaturation before tracheal tube placement is high, or laryngoscopy is felt to be very challenging or impossible, then RSI is not recommended. The only exception to this is in the "forced to act" scenario.

Critical Action: Perform "Awake" Laryngoscopy

Just as RSI is an essential technique of emergency airway management, "awake" intubation is the cornerstone of difficult airway management. The primary goal of this maneuver is to intubate the patient comfortably, while maintaining spontaneous respirations. This technique requires thorough topicalization of the airway and, sometimes, the judicious use of sedation in order to permit laryngoscopy (see Chapter 24). The principle here is that the patient is awake enough to maintain protective airway reflexes and effective spontaneous ventilation but is sufficiently anesthetized to tolerate an awake instrumentation of the airway. The laryngoscopy can be done orally with a flexible, video or direct laryngoscope or nasally with a flexible scope. Awake VL is preferred because the depth of blade insertion and force required to get an adequate view of the glottic inlet is less than that required with a conventional laryngoscope. These devices are discussed in detail in Chapter 16. Two outcomes are possible from this awake examination. First, the glottis is adequately visualized. In this situation, proceed with intubation. It could be tempting to withdraw, feeling confident that the airway can be visualized, and begin anew with RSI. Although this is a reasonable thought, subsequent laryngoscopy could prove more difficult, even with neuromuscular blockade. Therefore, we recommend completing the intubation during the awake look, provided the glottis is sufficiently visualized to permit intubation. The second possible outcome during the awake laryngoscopic examination is that the glottis is not adequately visualized to permit intubation. In this case, the examination has confirmed the suspected difficult intubation and reinforced the decision to avoid

neuromuscular paralysis. A failed airway has been avoided, and several options remain. Maintain oxygenation, as necessary, at this point.

Critical Action: Select an Alternative Airway Approach

At this point, we have clarified that we have a patient with difficult airway attributes, who has proven to be a poor candidate for laryngoscopy, and therefore is inappropriate for RSI. If oxygenation is maintained, there are several options available. If the awake orotracheal laryngoscopy was done using a direct laryngoscope, a video laryngoscope or flexible scope will likely provide a superior view of the glottis. Given the visualization advantage offered by VL, it should be considered a first-line device for awake orotracheal laryngoscopy. The main fallback method for the difficult airway is cricothyrotomy, although the airway may be amenable to an EGD that facilitates intubation, that is, one of the intubating LMAs (LMA Fastrach). In highly select cases, blind nasotracheal intubation may be possible but requires an anatomically normal upper airway. In general, blind nasotracheal intubation is used only when a flexible scope is not available or when there is excessive bleeding in the airway. The choice of technique will depend on the operator's experience, available equipment, the difficult airway attributes the patient possesses, and the urgency of the intubation. Irrespective of the technique used, the goal of difficult airway management is to place a cuffed ETT in the trachea. If oxygenation cannot be maintained, then the failed airway algorithm is invoked.

THE FAILED AIRWAY ALGORITHM

At several points in the preceding algorithms, it may be determined that airway management has failed. The definition of the failed airway (see previous discussion in this chapter and in Chapter 4) is based on one of three criteria being satisfied, the first being paramount: (i) a failure of any intubation attempt in a patient for whom oxygenation cannot be adequately maintained with a bag and mask or EGD, (ii) two unsuccessful intubation attempts by an experienced operator but with adequate oxygenation, and (iii) missed intubation using the one *best attempt* in the "forced to act" situation. Unlike the difficult airway, where the standard of care dictates the placement of a cuffed ETT in the trachea providing a definitive, protected

airway, the failed airway calls for action to provide emergency oxygenation sufficient to prevent patient morbidity (especially hypoxic brain injury and cardiac arrest) by whatever means possible, until a definitive airway can be secured (Fig. 5.5). Thus, the devices considered for the failed airway are somewhat different from, but inclusive of, the devices used for the difficult airway. When a failed airway has been determined to occur, the response is guided by whether oxygenation is possible.

Critical Action: Call for Assistance

As is the case with the difficult airway, it is best to call for any available and necessary assistance as soon as a failed airway is identified. Again, this action may be a stat consult to emergency medicine, anesthesia, or surgery, or it may be a call for special equipment. In the prehospital setting, a second paramedic or a medical control physician might provide assistance.

Key question 1: Is oxygenation adequate?

As is the case for the difficult airway, this question addresses the time available for a rescue airway. If the patient is a failed airway because of two failed attempts by an experienced operator, in most cases, oxygen saturation will be adequate, and there is time to consider various approaches. If, however, the failed airway is because of a CICO situation, then there is little time left before brain hypoxia ensues, and immediate action is indicated. Many, or most, CICO patients will require surgical airway management, and preparation for a surgical airway should be undertaken. It is reasonable, as the first rescue step, to make a single attempt to insert a rapidly placed extraglottic airway device, *simultaneously with the preparation for a cricothyrotomy.* Placement or even use of an EGD does not preclude a surgical airway should that device fail, yet successful oxygenation using the EGD converts the CICO situation into a *can't* intubate, *can* oxygenate situation, allowing time for consideration of several different approaches to securing the airway.

Achieve an airway using a flexible scope, a video laryngoscope, an EGD, or with a cricothyrotomy. In the can't intubate, *can* oxygenate situation, various devices are available to provide an airway, and most also provide some degree of airway protection. Intubation with a flexible or video laryngoscope will establish a cuffed tube in the trachea. Of the EGDs, the

intubating laryngeal mask airways (ILMAs) are preferable because they have a high likelihood of providing effective ventilation and usually permit intubation through the device either blindly or guided by a flexible endoscope (see Chapters 13 and 17). Cricothyrotomy always remains the final common pathway if other measures are not successful, or if the patient's oxygenation becomes compromised.

Key question 2: Does the device used result in a definitive airway?

If the device used results in a definitive airway (ie, a cuffed ETT in the trachea), then one can move on to PIM. If an EGD has been used, or intubation was not successful through the EGD, arrangements must be made to provide a definitive airway. A definitive airway may be provided in the operating room, ICU, or ED, once the necessary personnel and equipment are available. Until then, constant surveillance is required to ensure that the airway, as placed, continues to provide adequate oxygenation, with cricothyrotomy always available as a backup.

SUMMARY

These algorithms represent our most current thinking regarding a recommended approach to emergency airway management. The algorithms are intended as guidelines only. Individual decision-making, clinical circumstances, skill of the operator, and available resources will determine the final, best approach to airway management in any individual case. Understanding the fundamental concepts of the difficult and failed airway, identification, in advance, of the difficult airway, understanding the role of airway management in cardiac arrest, and the use of RSI, after physiologic optimization, as the airway management method of choice for most emergency intubations will foster successful airway management while minimizing preventable morbidity.

EVIDENCE

Evidence for the algorithms

Unfortunately, there are no systematized data supporting the algorithmic approach presented in this chapter. The algorithms are the result of careful review of the American Society of Anesthesiologists difficult airway

algorithm, the algorithms of the Difficult Airway Society of the United Kingdom, and composite knowledge and experience of the editors and faculty of The Difficult Airway Courses, who function as an expert panel in this regard.[1,2] There has not been, and likely never will be, a study comparing, for example, the outcomes of cricothyrotomy versus alternate airway devices in the CICO situation. Clearly, randomization of such patients is not ethical. Thus, the algorithms are derived from a comprehensive body of knowledge and represent a recommended approach but cannot be considered to be scientifically proven as the best way to approach any one clinical problem or patient. Rather, they are designed to help guide a consistent approach to both common and uncommon airway management situations. The evidence for the superiority of RSI over other methods not involving neuromuscular blockade and the performance characteristics of video versus direct laryngoscopy can be found in Chapters 20 and 16, respectively.

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CHAPTER 6

Human Factors During Emergency Airway Management

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INTRODUCTION

"It's a very difficult job and the only way to get through it is we all work together as a team. And that means you do everything I say."

Charlie Croker (as played by Michael Caine), in The Italian Job (Movie, 1969)

Any night in the emergency department, there is the potential for unrivaled drama. When managing airways, the individual challenges seem unpredictable, the team could be fractious, the environment perilous, and the cultural forces daunting. Regardless, it is about knowing your lines, understanding when it is safe (or necessary) to improvise, and committing to practice. It also means uniting individuals, with niche skills and different perspectives. The emergency clinician is at the helm and tasked with safely resuscitating a critically ill or injured patient, all the while multitasking, ensuring team preparedness, and grappling with a roomful of emotion. This chapter covers human factors (HFs), specifically, related to emergency airway management. It can be as important as the act of intubation itself and deserves every clinician's time and engagement.

Leadership and management during crises require expertise in both technical and nontechnical matters, and this chapter focuses on the nontechnical aspects of human performance: whether transcendent, mundane, or dangerous. HFs can be addressed using the umbrella term, crisis resource management (CRM), and subdivided into six sections:

situational awareness, decision-making, leadership and followership, teamwork, communication, and resource utilization.[1,2] Alternatively, HFs can be described at each pertinent level: individual, team, environment, system. We will use both approaches to offer a comprehensive one-stop primer. Regardless, just as technical competence is deliberately taught and practiced, rather than intuited, the same applies to nontechnical skills. We outline why HFs are so powerful and the basics of error. The goal in step three is to recognize triggers, mitigate flaws, and amplify skills (this is also known as "the aggregation of marginal gains").[3] Step four involves championing system-wide culture change. Whether airway management ends in triumph or tragedy depends on everyone.

The Importance of Human Factors: Why the Human Factor Is Always a Factor

HFs matter in any environment where humans perform. Moreover, the importance of HFs increases whenever there is complexity, time pressure, emotional stress, high stakes, and low error tolerance. Accordingly, HFs matter greatly in emergency airway management, and likely every bit as much as factual recall or manual dexterity.[2] As such, you cannot claim true airway expertise unless you understand how individuals, teams, environments, and systems succeed and fail.[4] Expressed another way, intubators, and airway teams, need to be as skilled with attention, emotion, and communication as with laryngoscopes. Verbal dexterity, and team dexterity, matters every bit as much as manual dexterity.

Aviation began formally studying HF half a century ago, following several high-profile crashes. Data showed at least 70% of adverse events could be attributed to the nontechnical.[5] Moreover, this high-risk-low-tolerance profession established that disaster could be averted by optimizing how humans and teams identify threats, make decisions, coordinate activity, and plan ahead. This appears to be true in airway management.[4,6,7] The difference is that medicine has lagged behind the aviation industry in terms of interrogating medical performance, optimizing culture, and mandating simulation. Moreover, whereas many argued whether medicine was more "art" or "science," aviation readily accepted that performance was as much "engineering" (ie, fail-safes, checklists, standard operating procedures) as

“psychology” (ie, maintaining cognitive bandwidth and using cognitive offloading).[2,4,8]

In short, it is still worth learning from aviation, even if the analogy has been oversimplified and overdone. Unlike scheduled flights, we cannot routinely delay emergency airway management until everyone is cognitively ready or rested. Similarly, it is rarely possible to make emergency landings if the “flight plan” goes awry. However, medicine and aviation do share a central, noble mission: to keep people safe, teams resilient, and situations predictable. Until medicine catches up, aviation offers insights into how individuals and teams manage stress, unfamiliarity, decision-making and distractions, and all are discussed in what follows.[9] Just like aviation’s passengers and pilots, medical patients and practitioners are at the mercy of a system supposed to keep us safe.

Like aviation, we should also embrace ergonomics, namely, the science of how humans perform in their environments, and whether we are “fit-for-task.” Medical ergonomics means looking at equipment design (ie, a laryngoscope handle), physical environments (ie, the sightlines in a resuscitation bay), and cognitive factors (how this helps us think and act). If we cannot think (afferent loop), then our actions (efferent loop) are more likely to be flawed. In everyday language: garbage in, garbage out.

There are untapped benefits from viewing airway management through an HF lens, rather than just the traditional biotechnical lens. Understanding HFs means placing patients at the center of a more robust system, reinforced with “safety nets,” “double checks,” “redundancies,” and “standard operating procedures.”[4] Once you embrace HFs, you see simulation (both mental rehearsal and team practice) as a social justice imperative, not a luxury.[10] HFs also highlight why we should regularly debrief (both immediately after an incident —the *hot* debrief—and later when emotions calm—the *cold* debrief).

Adopting an HF worldview can make teams more resilient. It shifts the focus from “why did you do that?” to the more nuanced, less ad hominem, “why did that seem appropriate at that time and place?”[6] It highlights how rudeness can be iatrogenic, because team members need to feel safe enough before speaking up.[11] It also explains why, at other times, we need those same team members to shut up, listen actively, but not take offense. It helps move away from assuming practitioners are lazy or incompetent (name,

blame, shame). HFs also highlight why team communication may be the most important "procedure" in medicine, emphasized by the often heard phrase: "meant is not said, said is not heard, heard is not understood and understood is not done."[12]

Understanding HFs can also encourage system-wide culture change.[13] Obviously, this is a longer-term project, but it is informed by similar ideals. As stated, HFs highlight the need to foster mutual respect and empathy, while stamping out toxicity or complacency. It means accepting that some hierarchy is needed, but not too much: otherwise, we will not leverage widespread knowledge and skills.[14] It means making team members feel valued. This is done by committing to longer-term career development rather than casting someone aside after one mistake. It means understanding that those actively talking are as important as those actively listening. It means understanding that although team leaders disproportionately set the tone, we all own the culture. It highlights the principle that safety is everybody's business and that safety matters as much as efficiency.[15]

ERROR BASICS: "TO ERR IS HUMAN…."

The quote "to err is human, to forgive divine" originated with the poet Alexander Pope in the 1700s. It was repurposed, in 1999, by the Institute for Health Improvement,[16] and emphasized that medicine has a serious safety problem. Recently, it underwent a tongue-in-cheek update: "to err is human; to blame others shows management potential." All three illustrate that humans are imperfect and that the pursuit of perfection is worthy but elusive. Regardless, preparation (eg, establishing, sharing, confirming, performing) can be literally lifesaving. Accordingly, the "airway plan A, B, C" is central to this concept. Although errors may be inevitable, bad outcomes are not.

The Swiss Cheese model illustrates why, when, and how errors occur; namely, when imaginary holes line up temporally and spatially.[17] It highlights that errors are often multifactorial, rather than a single individual's fault. It also explains why errors may not always lead to harm: sometimes we are lucky, sometimes we are good, sometimes we are protected. Good teams bake in safeguards (ie, a second laryngoscope and additional smaller endotracheal tubes [ETTs]). They also understand that

failures can be active and latent.[18] Active failures occur at the bedside and are hence easy to identify (ie, the intubator puts an ETT into the esophagus).[19] Latent failures are more often system problems and hence harder to identify and attribute, but no less important. They need a trigger, take time to occur, and are harder to diagnose, attribute, or remedy.[18]

Intubators need to be adept at getting tubes in airways—period, end of discussion. However, true airway experts take a broader view. They strive to minimize the likelihood, severity, and impact of both errors (decisions or actions that go against a standard) and mistakes (decisions or actions that turn out to be unhelpful). They accept that both errors and mistakes are more likely when individuals and teams are distracted, biased, or unfamiliar. They understand that both are more consequential when patients are acutely unstable or chronically frail. They share blame when active and latent errors occur and the responsibility to ensure they do not recur.[19] It starts with realizing that we can (and must) do better. After all, "if you think you can or you think you can't, you're probably right." Fortunately, there are practical CRM tools at the ready.

CRM: THE BIG SIX

The first CRM hurdle/opportunity is **situational awareness**, of which there are three levels: perception, comprehension, and projection. In everyday terms, this means (a) recognizing cues (ie, patient is tachypneic, hypercapnic, losing consciousness); (b) putting those cues together (ie, patient is in respiratory distress); and (c) predicting where this is headed (ie, patient could arrest if we don't intubate *now*). We can improve situational awareness by ensuring a shared mental model and requesting input to ensure everyone is on the same page and agrees with that current model.

CRM means understanding **decision-making** under stress. For example, there are three D's in the disaster response (denial, deliberation, and definitive action), and we can speed the transition using familiarity and by explicitly giving team members permission (eg, "if this attempt fails, we are placing an extraglottic device"). It also helps to understand the typical progression from novice to expert. This usually starts with being "consciously competent" (you know that you don't know—and hence are slow but easily taught). Next is "unconsciously competent" (you think you

know but don’t—and hence are less easily taught, and liable to overreach). Next is “consciously competent” (you are a great teacher but less efficient and less able to think ahead—often a senior trainee). Finally, there is the “unconsciously competent” (great reflexes, knows where this is going, but less able to explain to others). Another aspect of decision-making during crises is that we can only reliably manage a finite number of discrete elements, typically seven. The difference between novice and expert is how much can be packed into each of those seven boxes. If we fail, then it is often because novices became cognitive overloaded or experts became complacent.

This brings us to **task management,** where the goal is to optimize staff, equipment, space, and organizational processes. Task management can be impaired by poor role clarity, diffusion of responsibility, insufficient shared mental models, and failure to offload. These skills are especially perilous with “flash teams,” namely, those assembled quickly using unfamiliar members.

Leadership matters, especially when it is unclear who can do what or when members have different priorities and personalities.[20,21] Just like culture, leadership is hard to define, and we need to avoid slogans and buzzwords. Regardless, in airway management, an effective leader knows when to be hands-on (explicit leadership) and when to step back and delegate (implicit leadership).[14] Leaders have to simultaneously earn the team’s trust, present an acceptable shared mental model, centralize information flow, coordinate tasks, and overcome emotions.[12] They lead by example and accept disproportionate responsibility. Accordingly, leadership requires maturity and insight, not just more intubation experience.[21]

Hierarchy still matters, but you earn the right to lead; it is not just awarded on day one. Importantly, **followership** skills are no less important than leadership skills, even if, to date, there are 60 publications on leadership for every one publication on followership.[22] There is likely still a stigma associated with self-identifying as a follower (ie, a relative subordinate), even though 85% of health care workers of all ranks are better understood as followers. Health care simply could not function without skilled followers, and, once again, these skills can and should be taught. Effective followers step up when required and do not take it personally

when asked to step back. Clearly, followership is an advanced, impressive skill and should be valued as such.

Followers are able to self-manage and use emotional intelligence to size up what they can and should contribute in any moment.[14] Increasingly, the binary leader-or-follower is outdated. Instead, sophisticated airway team members move in and out of leadership and followership roles and put ego aside. There is also often a "first-follower," namely, one who bridges the roles by supporting the leader and encouraging the followers. Regardless, it is better to talk about high-functioning team members who possess the dexterity to adapt to *what* is needed (rather than *who* is in charge). Effective leaders and followers also cross monitor. This means we manage ourselves but stay vigilant to what others need. An effective team member has that "sixth sense," which lets them size up a situation and step up or step back in the best interests of the patient, team, and task.

In terms of **teamwork**, comprehensive airway management may necessitate subteams (ie, medication team, intubation team, hemodynamics team). This minimizes task overload, encourages cognitive offload, and maximizes role clarity. Subteams break the resuscitation into manageable chunks. This enables leaders to maintain a more supervisory role, or a "thousand-foot view."[23] This mirrors the two attention types seen in nature. System-1 is a focused spotlight gaze, exemplified by a predator, who focuses on what matters, namely, catching prey or the ABCs. System-2 means scanning from stimulus to stimulus. In nature, this is the prey who must avoid fixating on one spot and instead shift their attention between potential threats.[21] Leaders typically maintain a system-2 overview and shift focus between subtasks and subteams, and between taskwork and teamwork.[23] For example, the leader may be task focused until the ETT is secured. They then shift to ensuring the team is cooperating on other tasks. All of this requires excellent communication, a topic that deserves its own subheading.

COMMUNICATION

It takes time, humility, and commitment to become an expert communicator. It also takes skill to listen up and insight to shut up.[7] Silence is not always golden, nor is cacophony.[12] Three pillars of effective

communication are (a) closing the loop, (b) verbalizing thoughts and plans, and (c) maintaining a “sterile” resuscitation environment.

Language should be concise and precise, but also commonly understood. Also, avoid vague statements or mitigating phrases. There really is no room for “maybe” or “perhaps” or “somebody” or “sometime.” Every request should be amplified by confirming that it was heard and reconfirming when it is done (this is “closed-loop communication”). Mitigating language is so dangerous that it is the leading cause of commercial plane crashes. We typically use mitigating language because we lack confidence or are afraid to offend.[12] However, one need not be rude to be clear. An example of communication that is closed-loop and mitigation free is as simple as the following:

Team Leader: Senior resident, please intubate the patient, and confirm when successful (NOT “Would someone be able to intubate the patient”).
Resident: I am going to intubate the patient now.
Three minutes later
Resident: The patient has been intubated successfully.

Closed-loop communication includes three steps: directing a request to a specific individual, verbal acknowledgment, and confirmation that the request was completed successfully.[23] Graded assertiveness is also important when intimidated by authority. A useful approach is using the Concerned-Uncomfortable-Safety rule.[23]

Team Leader: Senior resident, please intubate the patient, and confirm when successful.
Resident: I am concerned that this will be a difficult airway due to facial trauma.
(Then, if response received is not adequate)
Resident: I am uncomfortable intubating this patient without assistance and advanced equipment.

If these red flags are not acknowledged, a “safety threat” can be declared. Moreover, because both members of the team understand the CUS model, it should decrease both reluctance and offense. Another method to advocate is the five-step approach. Developed, once again, by aviation, it involves: (a) attention getter, (b) statement of concern, (c) statement of the problem as you see it, (d) potential solution, and (e) a request for agreement.[12] This could look like the following:

Excuse me, Dr Smith. I am concerned this airway is difficult. I do not believe I am ready. I think we should get the difficult airway cart plus anaesthesia backup. Do you agree?

We should also verbalize thoughts and plans (ie, the leader asks, “What am I missing?”) and double-check before potentially dangerous actions are performed (ie, a nurse announces they are giving a paralytic). This not only promotes sharing but also allows for confirmation or reevaluation.[12] In emergency situations, this type of communication needs to be dispassionate and directed. The most important messages/questions should come first (“Does she have a pulse?”) followed by why (“The end tidal CO_2 is dropping; she may be about to arrest”).[24]

Effective communication is threatened when messages are excessively complex or when there is distraction from noise, emotion, or time pressure.[7] This increases the likelihood of misinterpretation because of information overload. Therefore, we should strive for a “sterile” resuscitation environment (pilots talk about a “sterile cockpit” and “flying by voice”). Team members must speak up when required yet recognize that critical moments (ie, takeoff or intubation) should be silent. During these moments, the intubator receives extra temporary power. Accordingly, everyone else’s comments are held, and those silenced should not take offense.[12]

The word “communication” means “sharing meaning and making understanding common.” Accordingly, it is the most important HF and the best way to identify if a team is high functioning. Importantly, communication is more than just delivered words. Communication can be divided into verbal (what is said), paraverbal (how it is said), and nonverbal (eye contact, facial expression, hand gestures). Just as expert teams know when to share key pieces of information, they are skilled (whether consciously or unconsciously) in each type of communication.[24] They also ensure that communication is consonant, not dissonant. This means that words match the tone and facial expression. Importantly, the words are the least important of the three communication subtypes. Saying “I don’t need help” but in a tone that suggests otherwise is not likely to be believed and therefore increases confusion and danger. Just ask for help; it is a sign of maturity.

As outlined, equally important to what is being said is how it is delivered. Four main tones exist: aggressive, submissive, cooperative, and

assertive.[7,25] The problem with excessively aggressive or submissive language is that it shifts the focus from what the patient needs to the status and ego of various team members. Modern clinicians are increasingly expected to use more cooperative/assertive styles and to further fine-tune based on the situation's urgency and the team's experience.

Handover between teams can be equally perilous. Therefore, we need to practice and perfect it, every bit as much as handwashing. As patients make their way from prehospital to the emergency room to the operating room and beyond, each creates an opportunity for error, akin to the game of broken telephone. SBAR (Situation, Background, Assessment, and Recommendation) is a widely recognized and effective strategy. It was developed by the military and ensures that handover is succinct and comprehensive. Importantly, it is widely known. This means that those on the receiving end should recognize when the last component (ie, the all-important "recommendation") is missing. In airway management this helps with role clarity (ie, "are you calling for backup or for me to take over?").[12]

Debriefings allow teams to explore what went right and wrong. They are an opportunity to improve and identify when formal or informal reviews are required.[26] They are a time to let off steam, share emotions, bond, and explore ethical or moral concerns.[27] Debriefings need to be routine, not exceptional, and occur when things go right, not just wrong.

INDIVIDUAL FACTORS

Stress and Other Adverse Physiologic States

Stress affects performance. Low stress is tolerable, and likely preferable, whereas excess stress impairs performance in the short term and health in the long term. When pressure is applied, performance can be imagined on a spectrum with three main states: disengagement (insufficient stress), flow (optimal stress), and frazzle (overstress), shown in **Figure 6.1**.[20] Flow is optimal because we are aroused and focused, but flexible. In contrast, frazzle inhibits high-level thought and narrows attention. It impairs the ability to step back to assess the whole situation. When stressed, we rely on old patterns and are less able to innovate or problem solve. In the worst-case scenario, we freeze.[20]

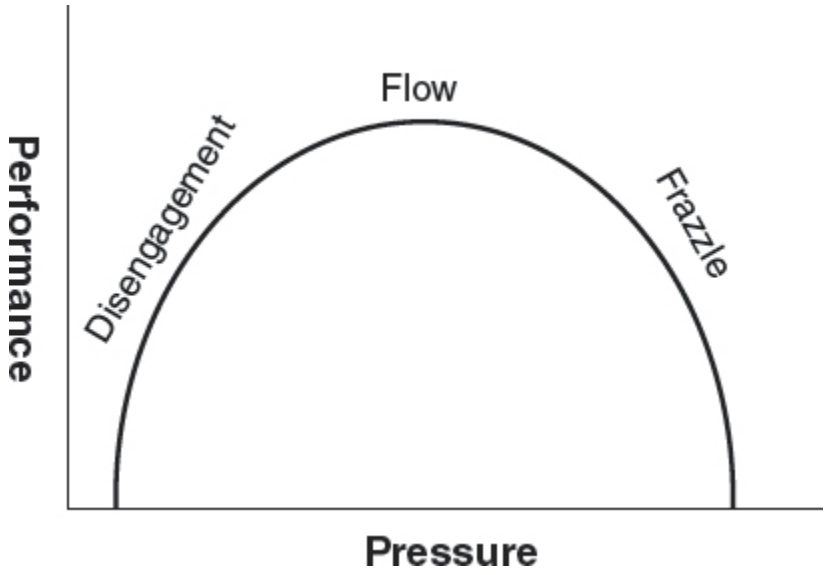

Figure 6.1: A performance curve demonstrating the optimal level of pressure to achieve peak performance (flow).

With excess stress, humans get tunnel vision. In theory, this means we focus only on immediate threats, and as a result, important peripheral clues can be missed. Similarly, tunnel action can occur, leading to perseveration and persistence, regardless of whether the action is helpful or harmful. Rote actions, or those from the past, become dominant because they are easier to access and familiar. For example, the intubator may try laryngoscopy over and over, long after it was time to move on to plan B.[24]

"Goldilocks" stress (not too much, not too little) is illustrated by the Yerkes-Dodson curve and lives somewhere between "this is boring and routine" and "my hands are shaking; I can't think or act."[28,23] However, what is terrifying for some may be exhilarating for others. Stress response depends on prior experience and personality.[23] Stress inoculation training can be useful because it involves deliberate graduated stress exposure. It is also a way to prevent medical simulations from becoming monotonous (for the experienced) or threatening (for novices).[24]

Perception easily becomes reality. For example, if an intubator feels that demands exceed resources, then they are likely to feel under threat and therefore underperform. This could include doubting their airway ability, their assistants, their equipment or suspecting they will be pilloried for any mistake. These triggers create sympathetic overactivity and impairs task execution.[29] The same airway can be reframed as "a challenge rather than a

threat" if another intubator believes their resources and skills match or exceed the demands.

Regarding other adverse physiologic states, the aviation acronym "IM SAFE"[30] encourages self-reflection. The acronym highlights the effects of illness, medications, stress, alcohol, fatigue, and emotions. Although, obviously, no health care worker or pilot should ever work intoxicated, the acronym reminds us that sleep deprivation can have a similar impact on performance as alcohol. In the short term, both comprise higher cognitive skills and decision-making and in the long term impairs mental and cardiovascular health.[31,32] The medical profession still downplays sleep importance, one of our most basic human needs. We forget that "to do well we must be well." We recommend a self-check before starting a shift or managing that airway.

Cognitive Readiness

We cannot always control when airways are anatomically or physiologically difficult, but we can influence their situational difficulty.[2] By maximizing our cognitive readiness, we can mitigate our vital signs.[33] Techniques include breathing techniques, self-affirmation, and mental rehearsal. Each is easy to learn and requires but a few moments.

Controlled breathing involves four steps, each lasting four seconds: slow, deep inspiration, then breath holding, then slow full expiration, then breath holding. It is similar to mindfulness and meditation and can be done before, during, or after critical events.[15] Positive self-talk, or self-affirmation, involves reminding yourself that you have successfully intubated many times. This can decrease self-doubt and reframe negative thoughts.[23] Mental rehearsal or cognitive imagery (preimagining a successful sequence of events) increases confidence and subjective control.[29] Watch any Olympian prior to competing, and you can imagine that spectacular dive or ski run in their eyes before it happens.

Cognitive Bias

Beliefs and actions are influenced by prior experience, both successes and failures. When overstressed, we over rely on what we did before. This is dangerous if it results in overly simplistic answers to complex problems.[6]

Importantly, however, pattern recognition can also be lifesaving and time-saving. After all, maybe it did work before, and it did avoid perilous delays. Clearly, there is a balance between "analysis paralysis" and seeing patterns where we should not. Sometimes, it is a case of "don't just stand there, do something," whereas other times "don't just do something, stand there."[20]

Although humans are capable of emotion, depth, and abstraction—things that cannot yet be done by most computers—we can be unpredictable, irrational, distractible, and fatigable. We are open to bias. These include downplaying contrary evidence (premature closure), sticking with initial assumptions (anchoring heuristics), prioritizing ideas that come to mind easily (availability heuristics), and ignoring alternatives (fixation errors). Importantly, these biases are rarely deliberate and rarely caused by inadequate medical knowledge. Solutions include thinking about how we think and accepting that despite our best efforts, and hero-narrative, we are as prone to error as to genius. Now, instead of just one human, let's multiple by four or five. In other words, let's now optimize the health care team.

TEAM FACTORS

The Prebrief and the Zero Point Survey

Every medical trainee is taught that resuscitation starts with a primary survey (the ABCs). However, there is often time before the patient arrives and before resuscitation begins. This should not be wasted; hence the additional, preemptive, Zero Point Survey (ZPS, see **Fig. 6.2**).[33] It is intended to improve cognitive readiness at all levels. Specifically, it prepares the **S**elf, **T**eam, **E**nvironment and **P**atient and calls for **U**pdates and explicit **P**riorities: hence the **STEP UP** mnemonic. In brief, **S**elf-preparation uses the aforementioned IM SAFE checklist (see earlier). **T**eam preparation means assigning clear roles (ie, the intubator, the second physician, the respiratory therapist, the drug administrator) and prebriefing (Plan A, B, and C). The **E**nvironment is then optimized (ie, bring the Difficult Airway Kit closer, or clear the hallways). The **P**atient is then assessed and positioned. Any **U**pdates are incorporated into the shared mental model, which can occur during the procedure (ie, beware, the blood

pressure is already low). **P**riorities are established, for example, confirming postintubation end tidal CO_2 and hemodynamic stability.

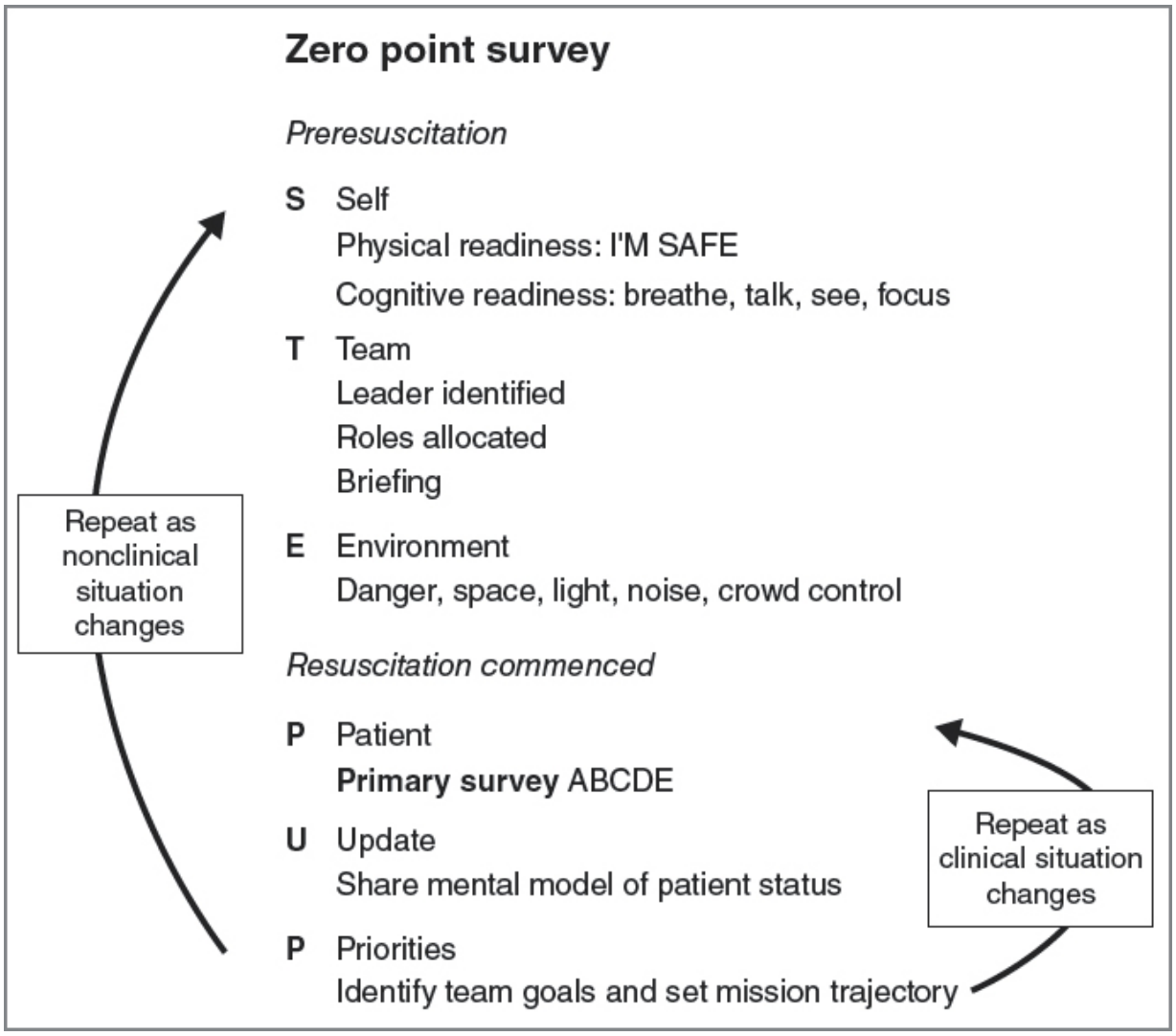

Figure 6.2: The STEP-UP approach to the Zero-Point Survey, preceding and commencing with patient arrival. (From Reid C, Brindley P, Hicks C, et al. Zero point survey: a multidisciplinary idea to STEP UP resuscitation effectiveness. *Clin Exp Emerg Med*. 2018;5(3):139-143.)

It has been argued that "failing to plan is like planning to fail." A prebrief also provides an excellent time to tell team members that you appreciate their presence and to encourage members to share concerns. Everyone on the team should have the opportunity to verbalize concerns.[23] Prebriefing also lets the team, not just the intubator, own the plan and outcome. If chaos ensues, you have a preagreed upon fallback plan. In

short, the team has a roadmap for excellence because they have prepared for a disaster.

Team Mental Models

As outlined, situational awareness consists of three parts: absorb cues, synthesize to create meaning, and predict what should happen next.[21] Teams that do all three exemplify "adaptive coordination." In aviation terms, this means "flying ahead of the plane." In airway management terms, it means not letting the patient go anywhere your brain has not already been.[4,23] For teams to able to adapt, members need to be on the same page, especially as things evolve. In other words, they need a robust, and adaptable, mental model. This is usually communicated by the leader and strengthened and/or modified when team members share information. The best leaders seek input from others and share regular updates.[23]

Much like the ZPS, the mental model includes a common understanding of assignments, priorities, context, and resources.[6,15] Although we should avoid excessive noise, the process of "resuscitating by voice" is one way to keep team members on the same page.[24] The hierarchy gradient is also important in the shared mental model. If excessive, it discourages subordinates from speaking up. If insufficient, it provides poor clarity and diffused responsibility. Experienced airway teams typically use low authority gradients (aka horizontal authority). This means team members speak and leaders say less.[12] Less experienced teams need more explicit coordination and more vertical authority gradients, akin to command and control.[4] Shared mental models can also increase collective calm because they not only provide a shared psychological roadmap but also free up bandwidth for novel complex tasks.

COGNITIVE AIDS

Cognitive aids exist in the form of checklists, algorithms, or mnemonics. They can replace chaos with structure, provide a shared understanding of key steps, and rescue those too stressed to make decisions or carry out tasks. Accordingly, checklists are well suited to airway management and can save lives. However, they are no panacea. They should be used to take care of the simple, thereby freeing up brains for decisions that require

nuance and flexibility. Checklists also need to be pressure-tested to determine whether they help, hurry, hinder, or delay. Importantly, they are also a guide, not a mandate, and not a replacement for judgment and experience.

Airway experts are familiar with the tragic death of Elaine Bromiley from peri-intubation anoxic brain injury.[34] A checklist or guideline, such as that put forth by the Difficult Airway Society, could have been lifesaving.[35] But you can also overdo checklists. For example, there are 38 published checklists and guidelines for the challenging airway alone: far too many when disaster strikes.[36] Ultimately, checklists are tools and are only as good as the ones using them. Like medications, checklists should be administered for the right indication, at the right time, and by the right people. They should be concise (less than seven items), should pose questions, and justify the precious time they consume.[2] Good cognitive aids are simulation tested and open to refinements based on team feedback.[26,36] They should be in large font and visibly displayed where they will be used. Although not solely for airway management, we are fans of the Resuscitation Crisis Manual.[39] **Figure 6.3** shows another example of a brief cognitive aid that can be used in airway management outside of the operating room (aka AMOTOR).[2]

P – Preoxygenate position

Do not remove oxygen. Increase supplemental oxygen. Align the patient's airway axes.

R – Reset; Resist

Increase frequency of vitals. Do not prematurely lay the patient flat. Empty the stomach.

E – Examine; Explicit

Examine the airway. Identify the cricothyroid membrane. Avoid vague commands; escalate assertiveness

P – Plan A, Plan B

Identify, announce, share plan A/B/C. Ensure it is the right plan. Gather equipment and personnel.

A – Adjust; Attention

Adjust anesthetic agents and doses. Consider "push-pressors." Ensure system-I and 2 attention.

R – Remain; Review

Do not leave the patient prematurely. Perform a head-to-toe review. Announce future concerns.

E – Exit; Explore

Announce when you need to change the plan. Coordinate transfer/handover. Debrief entire team.

Figure 6.3: The PREPARE mnemonic for airway management outside the operating room. (Reprinted by permission from Springer Nature: Brindley PG, Beed M, Law JA, et al. Airway management outside the operating room: how to better prepare. *Can J Anesth*. 2017;64(5):530-539.)

ENVIRONMENTAL CONSIDERATIONS

Safe airway management requires more than shiny tools and skilled hands. It needs to be performed in an environment place that has "been made safe." The head of the bed must be accessible, obstacles removed, the airway cart nearby, and monitors visible. There should be proper lighting and space for the team to function, but not so big that team members have to shout. Equipment poses unique threats: it can stop working, it can be forgotten, or it can be user unfriendly. Equipment, and its location, should be standardized and backups handy. New equipment should not be used until simulations have occurred.[20] The resuscitation environment should be scanned for latent threats. These include obstacles around the bed, faulty oxygen tubing, and misplaced supplies.[37,38] The location and labeling of all necessary equipment should be widely known.

SAFETY-I AND SAFETY-II

To date, safety has largely been defined by the absence of failure. This has meant a mantra of "minimal variation and maximal compliance." This approach is valid for many airways but not all. The "find and fix" strategy (now known as safety-I) assumes errors are pervasive, and job-one is to bring health care practitioners into line.[39,40] This worldview also encourages a bimodal worldview: "things went right or wrong." It fails to appreciate complexity and assumes humans are a liability.[40] It is attractive to those in administration and encourages rigid standardization and top-down control. Front lines know that health care is more nuanced; hence, safety-II: the complementary study of how things go right.

Health care is often unpredictable, yet airway management is usually successful and uneventful. This is because humans are problem solvers who adapt and function despite complexity and chaos. The safety-II worldview highlights the need to empower frontliners and respect gestalt and experience. Safety-II studies successes, rather than just failures. It sees

excessive standardization, not variation, as the liability. Not surprisingly, the way forward requires balance. Safety-I may work for straightforward airways, with Safety-II for the more complex. Excessive Safety-I risks blaming, disengaging, and "burning out" practitioners. Safety-II seeks their engagement and could bolster well-being.[39] Importantly, health care providers want to do the right thing because of the system, not despite it. The perceived inability to do so can cause moral distress and disengagement. Anyone who can grasp the basics of HFs would understand why getting airway safety wrong could be tragic.

TIPS AND PEARLS

- The more difficult, chaotic, and unpredictable the airway, the more that HFs will be the difference between life and death.
- Teams need to hone their communication and take pride in *both* leadership and followership roles.
- The environment should be optimized both for thinking and for doing, and this includes using cognitive aids that help, not hinder.
- Systems must be open to dialogue and see frontliners as assets and partners, not liabilities or annoyances.
- Culture change takes much longer than tracheal intubation but is just as important.

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CHAPTER 7

Applied Functional Anatomy of the Airway

Michael F. Murphy

INTRODUCTION

There are many salient features of the anatomy and physiology of the airway to consider with respect to airway management maneuvers. This chapter discusses the anatomic structures most involved in airway management and the innervation of the upper airway. Chapter 24 builds on these anatomic and functional relationships to describe anesthesia techniques for the airway. Chapter 25 addresses developmental and pediatric anatomic features of the airway.

This chapter describes anatomic structures in the order in which they appear as we enter the airway: the nose, the mouth, the pharynx, the larynx, and the trachea (**Fig. 7.1**).

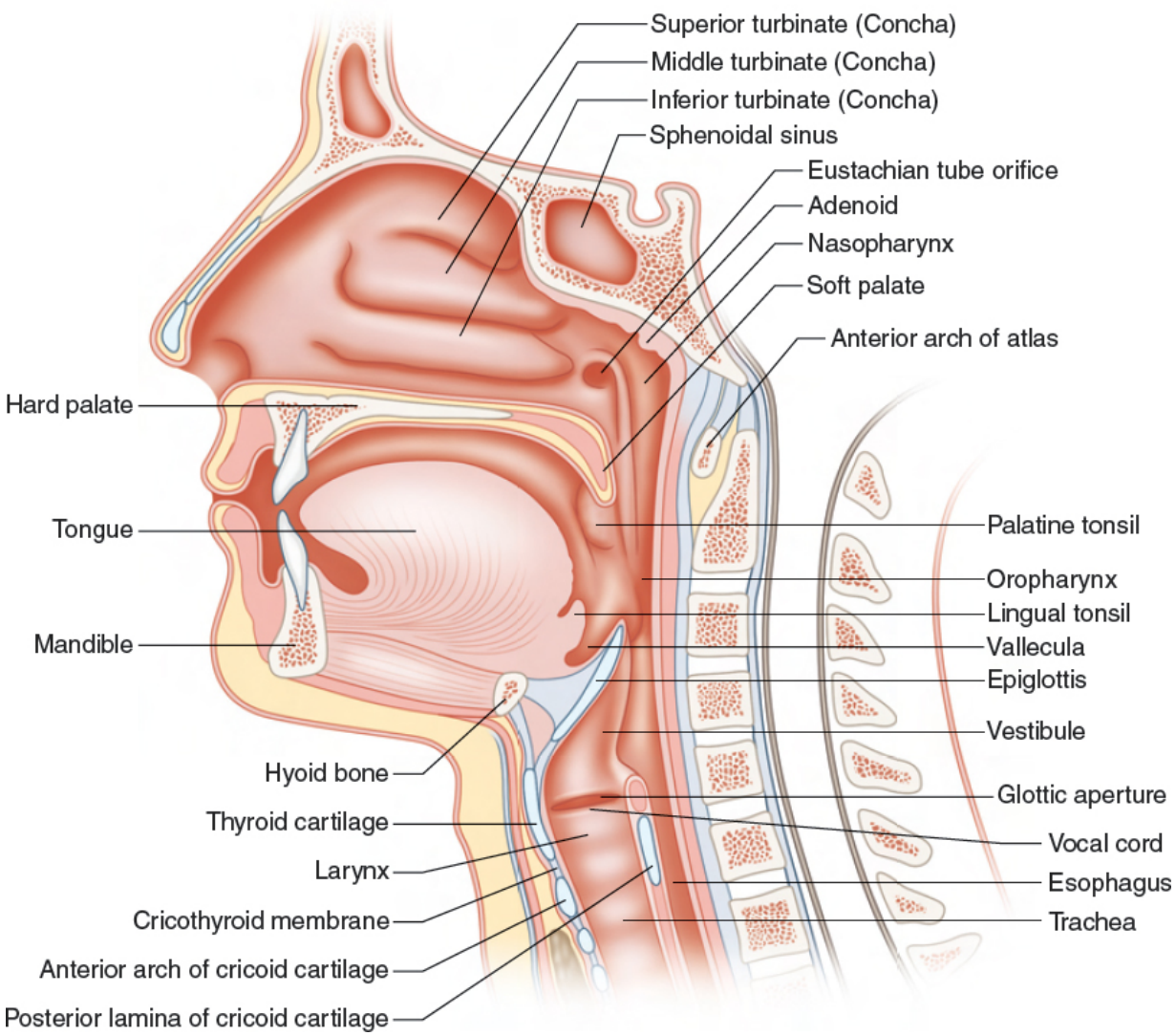

Figure 7.1: Sagittal view of the upper airway. Note the subtle inferior tilt of the floor of the nose from front to back, the location of the adenoid, the location of the vallecula between the base of the tongue and the epiglottis, and the location of the hyoid bone in relation to the posterior limit of the tongue.

THE NOSE

The external nose consists of a bony vault, a cartilaginous vault, and a lobule. The bony vault comprises the nasal bones, the frontal processes of the maxillae, and the nasal spine of the frontal bone. The nasal bones are buttressed in the midline by the perpendicular plate of the ethmoid bone that forms part of the bony septum. The cartilaginous vault is formed by the upper lateral cartilages that meet the cartilaginous portion of the septum in the midline. The nasal lobule consists of the tip of the nose, the lower

lateral cartilages, the fibrofatty alae that form the lateral margins of the nostril, and the columella. The cavities of each nostril are continuous with the nasopharynx posteriorly.

Important Anatomic Considerations

- Kiesselbach plexus (Little's area) is a very vascular area located on the anterior aspect of the septum in each nostril. Epistaxis most often originates from this area. During the act of inserting a nasal trumpet or a nasotracheal tube (NTT), it is generally recommended that the device be inserted in the nostril such that the leading edge of the bevel (the pointed tip) is away from the septum. The goal is to minimize the chances of trauma and bleeding from this very vascular area. This means that the device is inserted "upside down" in the left nostril and rotated 180° after the tip has proceeded beyond the cartilaginous septum. Although some authors have recommended the opposite (ie, that the bevel tip approximate the nasal septum to minimize the risk of damage and bleeding from the turbinates), the bevel away from the septum approach makes more sense and is the recommended method.
- The major nasal airway is between the laterally placed inferior turbinate, the septum, and the floor of the nose. The floor of the nose is tilted slightly downward front to back, approximately 10° to 15°. Thus, when a nasal tube, trumpet, or flexible endoscope is inserted through the nose, it should not be directed upward or even straight back. Instead, it should be directed slightly inferiorly to follow this major channel. Before nasal intubation of an unconscious adult patient, this author recommends gently but *fully* inserting one's gloved and lubricated little finger into the nostril to ensure patency and to maximally dilate this channel before the insertion of the nasal tube. In addition, placing the endotracheal tube (ETT; preferably an Endotrol tube) in a warm bottle of saline or water softens the tube and attenuates its damaging properties.
- The nasal mucosa is exquisitely sensitive to topically applied vasoconstricting medications such as phenylephrine, epinephrine, oxymetazoline, or cocaine. Cocaine has the added advantage of providing profound topical anesthesia and is the only local anesthetic

agent that produces vasoconstriction; the others cause vasodilatation. Shrinking the nasal mucosa with a vasoconstricting agent can increase the caliber of the nasal airway by as much as 50% to 75% and may reduce epistaxis incited by nasotracheal intubation, although there is little evidence to support this claim. Cocaine has been implicated in coronary vasoconstriction when applied to the nasal mucosa, so it should be used with caution in patients with coronary artery disease. Topical cocaine is rarely available or used in emergency medicine. Evidence suggests that topical vasoconstrictor and local anesthetic agents are not necessary to perform flexible nasoendoscopy (see "Evidence" section that follows).

- The nasal cavities are bounded posteriorly by the nasopharynx. The adenoids are located posteriorly in the nasopharynx just above the nasal surface of the soft palate and partially surround a depression in the mucosal membrane where the eustachian tube enters the nasopharynx. During insertion, the NTT often enters this depression, and resistance is encountered. Continued aggressive insertion can cause the NTT to penetrate the mucosa and pass submucosally deep to the naso- and oropharyngeal mucous membranes (**Fig. 7.2**). Although it is alarming when one recognizes that this has occurred, no specific treatment is indicated, except withdrawing the tube and trying the opposite nostril should nasal intubation be deemed appropriate. Despite the theoretical risk of infection, there is no literature to suggest that this occurs. Documentation of the complication and communication to the accepting team on admission is important.

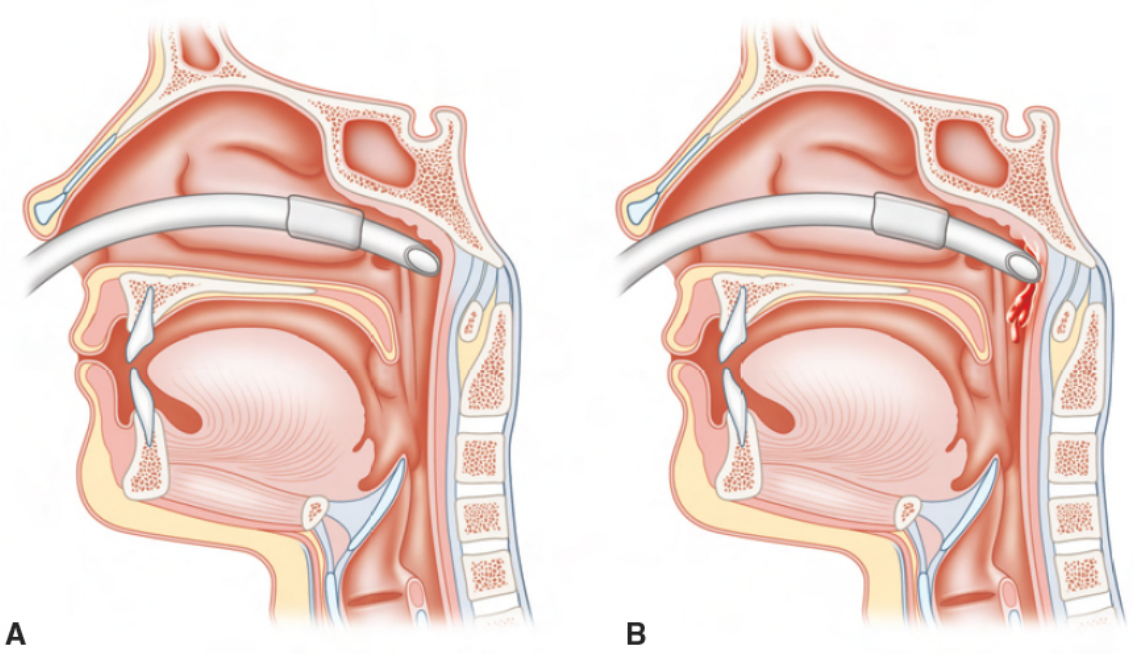

Figure 7.2: Mechanism of nasopharyngeal perforation and submucosal tunneling of the NTT. A: The NTT entering the pit of the adenoid where the eustachian tube enters the nasopharynx. B: The tube perforating the mucous membrane; NTT, nasotracheal tube.

- The soft palate rests on the base of the tongue during quiet nasal respiration, sealing the oral cavity anteriorly.
- The contiguity of the paranasal sinuses with the nasal cavity is believed to be responsible for the infections of the paranasal sinuses that may be associated with prolonged nasotracheal intubation. Although this fact has led some physicians to condemn nasotracheal intubation, fear of infection should not deter the emergency physician from performing nasotracheal intubation when required. Securing the airway in an emergency takes precedence over possible later infective complications, and in any case, the intubation can always be changed to an oral tube or tracheostomy, if necessary.
- A nasotracheal intubation is relatively contraindicated in patients with basal skull fractures (ie, when the maxilla is fractured away from its attachment to the base of the skull) because of the risk of penetration into the cranial vault (usually through the cribriform plate) with the ETT. Careful technique avoids this complication: The cribriform plate is located cephalad of the nares, and tube insertion should be directed

slightly caudad (see previous discussion). Maxillary fractures (eg, Le Fort fractures) may disrupt the continuity of the nasal cavities and are a relative contraindication to blind nasal intubation. Again, cautious insertion, especially if guided by a flexible endoscope can mitigate the risk.

THE MOUTH

The mouth, or oral cavity, is bounded externally by the lips and is contiguous with the oropharynx posteriorly (**Fig. 7.3**).

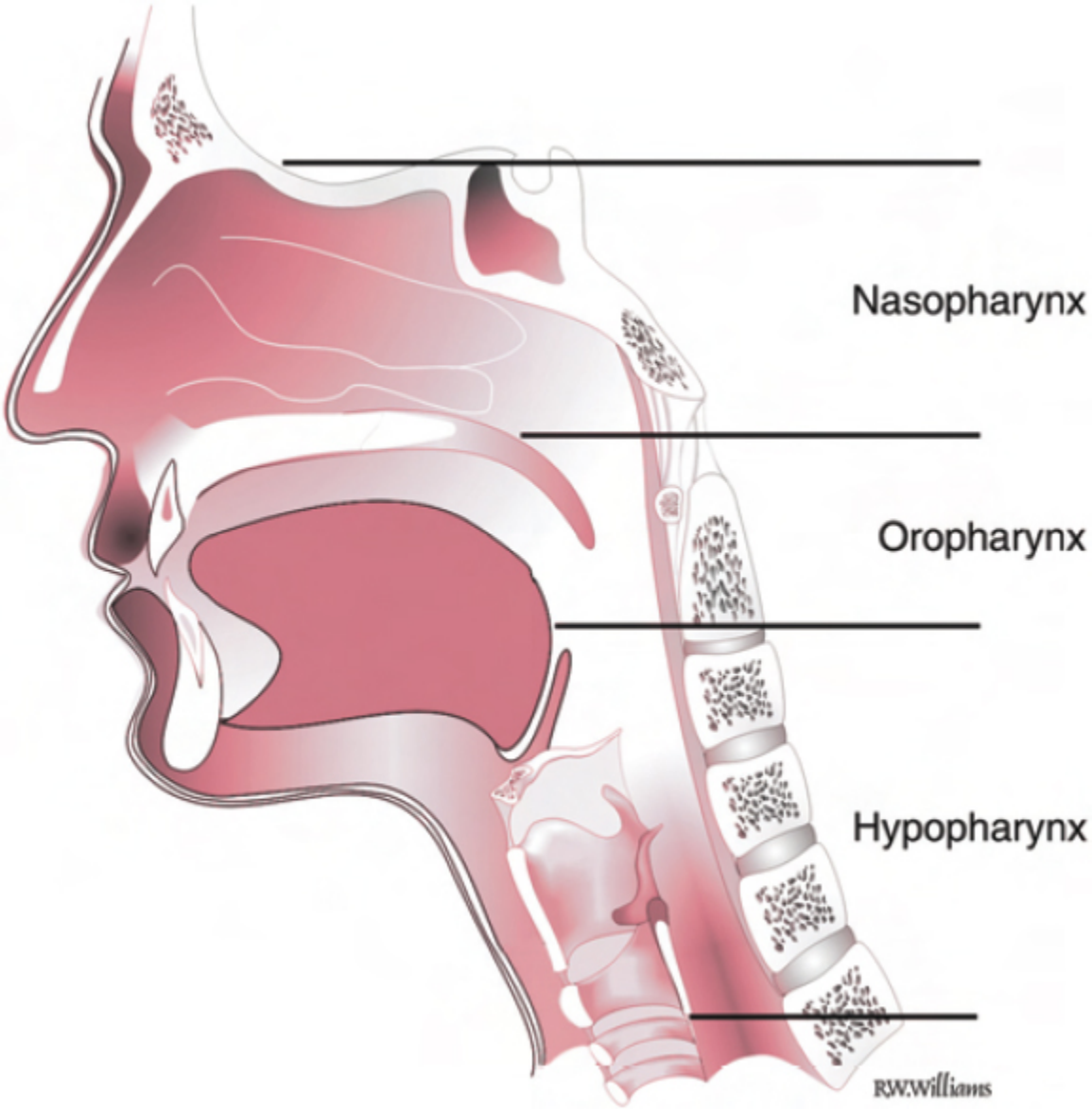

Figure 7.3: Pharynx divided into three segments: nasopharynx, oropharynx, and hypopharynx.

- The tongue is attached to the symphysis of the mandible anteriorly and anterolaterally and the stylohyoid process and hyoid bone posterolaterally and posteriorly, respectively. The hyoid is connected to the epiglottis by the hyoepiglottic ligament. The clinical relevance of this relationship explains why a jaw thrust pulls the epiglottis anteriorly exposing the laryngeal inlet. The posterior limit of the tongue corresponds to the position of the hyoid bone (Fig. 7.1).
- The potential spaces in the hollow of the mandible are collectively called the mandibular space, which is subdivided into three potential spaces on either side of the midline sublingual raphe: the submental, submandibular, and sublingual spaces. The tongue is a fluid-filled noncompressible structure. During direct laryngoscopy, the tongue is ordinarily displaced to the left and into the mandibular space (volume), permitting one to expose the larynx for intubation under direct vision. If the mandibular space is small relative to the size of the tongue (eg, hypoplastic mandible, lingual edema in angioedema, and lingual hematoma), the ability to visualize the larynx may be compromised. Infiltration of the mandibular space by infection (eg, Ludwig's angina), hematoma, or other lesions may limit the ability to displace the tongue into this space and render orotracheal intubation difficult or impossible.
- Subtle geometric distortions of the oral cavity that limit one's working and viewing space, such as a high-arched palate with a narrow oral cavity or buckteeth with an elongated oral cavity, may render orotracheal intubation difficult. Chapter 15 elaborates on these issues.
- Salivary glands continuously secrete saliva. This can hinder attempts at achieving sufficient topical anesthesia of the airway to undertake awake laryngoscopy or other active airway intervention maneuvers in the awake or lightly sedated patient—for example, laryngeal mask airway insertion.
- The condyles of the mandible articulate within the temporomandibular joint (TMJ) for the first 30° of mouth opening. Beyond 30°, the condyles *translate* out of the TMJ anteriorly onto the zygomatic

arches. After translation has occurred, it is possible to use a jaw thrust maneuver to pull the mandible and tongue forward. This is the most effective method of opening the airway to alleviate obstruction or permit bag-mask-ventilation. A jaw thrust to open the airway may not be possible unless this translation has occurred (see Chapter 12).

THE PHARYNX

The pharynx is a U-shaped fibromuscular tube extending from the base of the skull to the lower border of the cricoid cartilage where, at the level of the sixth cervical vertebra, it is continuous with the esophagus. Posteriorly, it rests against the fascia covering the prevertebral muscles and the cervical spine. Anteriorly, it opens into the nasal cavity (the nasopharynx), the mouth (the oropharynx), and the larynx (the laryngo- or hypopharynx).

- The oropharyngeal musculature has a normal tone, like any other skeletal musculature, and this tone serves to keep the upper airway open during quiet respiration. Respiratory distress is associated with voluntary pharyngeal muscular activity that attempts to open the airway further. Benzodiazepines and other sedative hypnotic agents may attenuate some of this tone. This explains why even small doses of sedative hypnotic medications (eg, midazolam) may precipitate total airway obstruction in patients presenting with partial airway obstruction.
- An “awake look” employing direct or indirect laryngoscopy to see the epiglottis or posterior glottic structures using topical anesthesia and sedation may reassure one that at least this much, and probably more, of the airway will be visualized during laryngoscopy and intubation following the administration of a neuromuscular blocking drug. In practice, the glottic view is usually improved following neuromuscular blockade. Rarely, however, the loss of pharyngeal muscle tone caused by the neuromuscular blocking agent leads to the cephalad and anterior migration of the larynx, worsening the view at direct laryngoscopy. Although uncommon, this tends to occur more often in morbidly obese or late-term pregnancy patients, in whom there may be submucosal edema.

- The glossopharyngeal nerve supplies sensation to the posterior one-third of the tongue, the valleculae, the superior surface of the epiglottis, and most of the posterior pharynx. It mediates the gag reflex. This nerve is accessible to blockade (topically or by injection) because it runs just deep into the inferior portion of the palatopharyngeus muscle (the posterior tonsillar pillar) (**Fig. 7.4**).

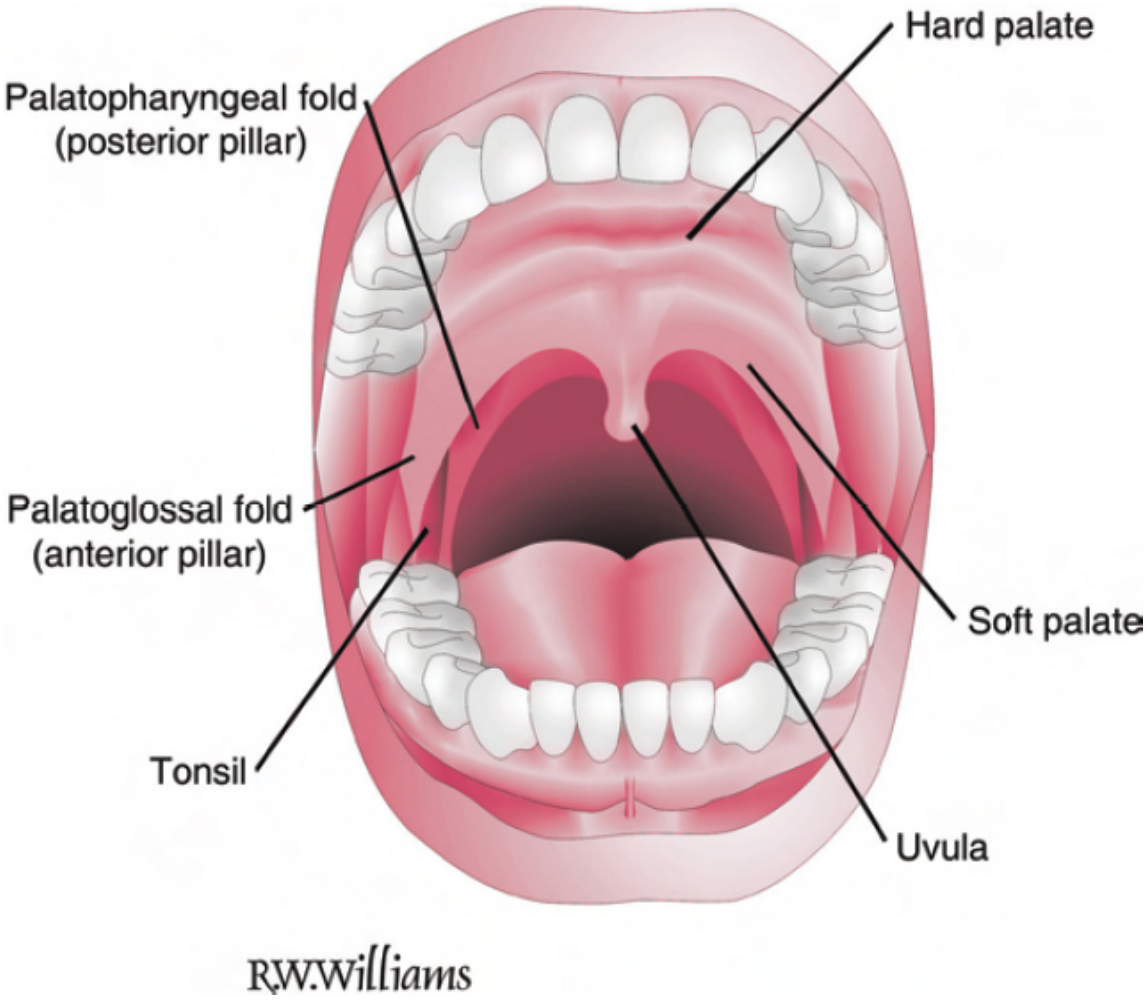

Figure 7.4: The oral cavity. Note the position of the posterior tonsillar pillar. The glossopharyngeal nerve runs at the base of this structure.

THE LARYNX

The larynx extends from its oblique entrance formed by the aryepiglottic folds, the tip of the epiglottis, and the posterior commissure between the

arytenoid cartilages (interarytenoid folds) through the vocal cords to the cricoid ring (**Fig. 7.5**).

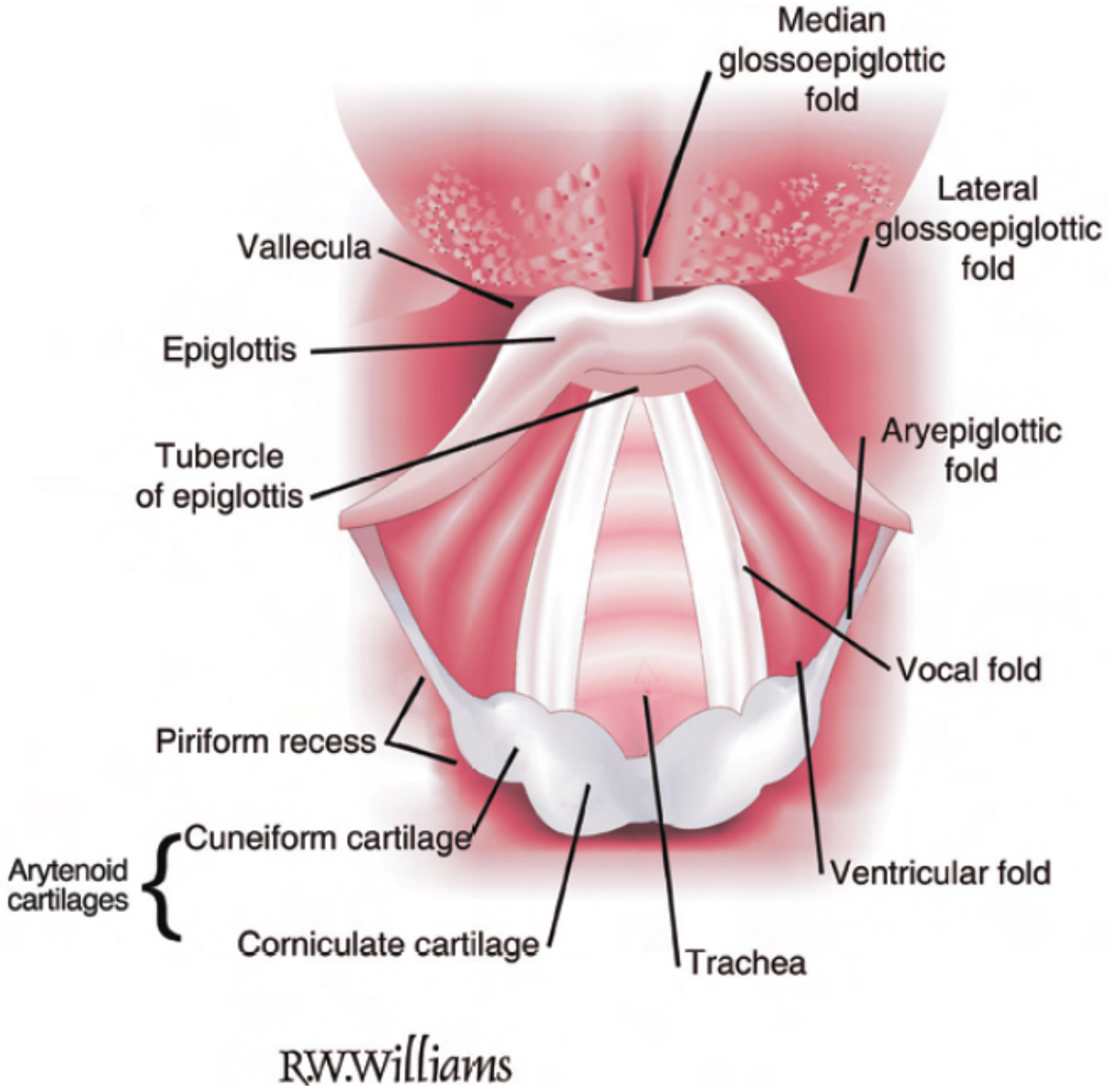

Figure 7.5: Larynx visualized from the oropharynx. Note the median glossoepiglottic fold covering the hyoepiglottic ligament in the center of the vallecula. It is pressure on this structure by the tip of a curved blade that flips the epiglottis forward, exposing the glottis during laryngoscopy. Note that the valleculae and the piriform recesses are different structures. The cuneiform and corniculate cartilages are called the arytenoid cartilages. The ridge of tissue between them posteriorly is called the posterior commissure.

- The superior laryngeal branch of the vagus nerve supplies sensation to the undersurface of the epiglottis, all of the larynx to the level of the

false vocal cords, and the piriform recesses posterolateral to either side of the larynx (Fig. 7.5). The nerve enters the region by passing through the thyrohyoid membrane just below the inferior cornu of the hyoid bone (**Fig. 7.6**). It then divides into a superior and an inferior branch: the superior branch passes submucosally through the vallecula, where it is visible to the naked eye, on its way to the larynx; and the inferior branch runs along the medial aspects of the piriform recesses where it is also sufficiently superficial to be visible to the naked eye.

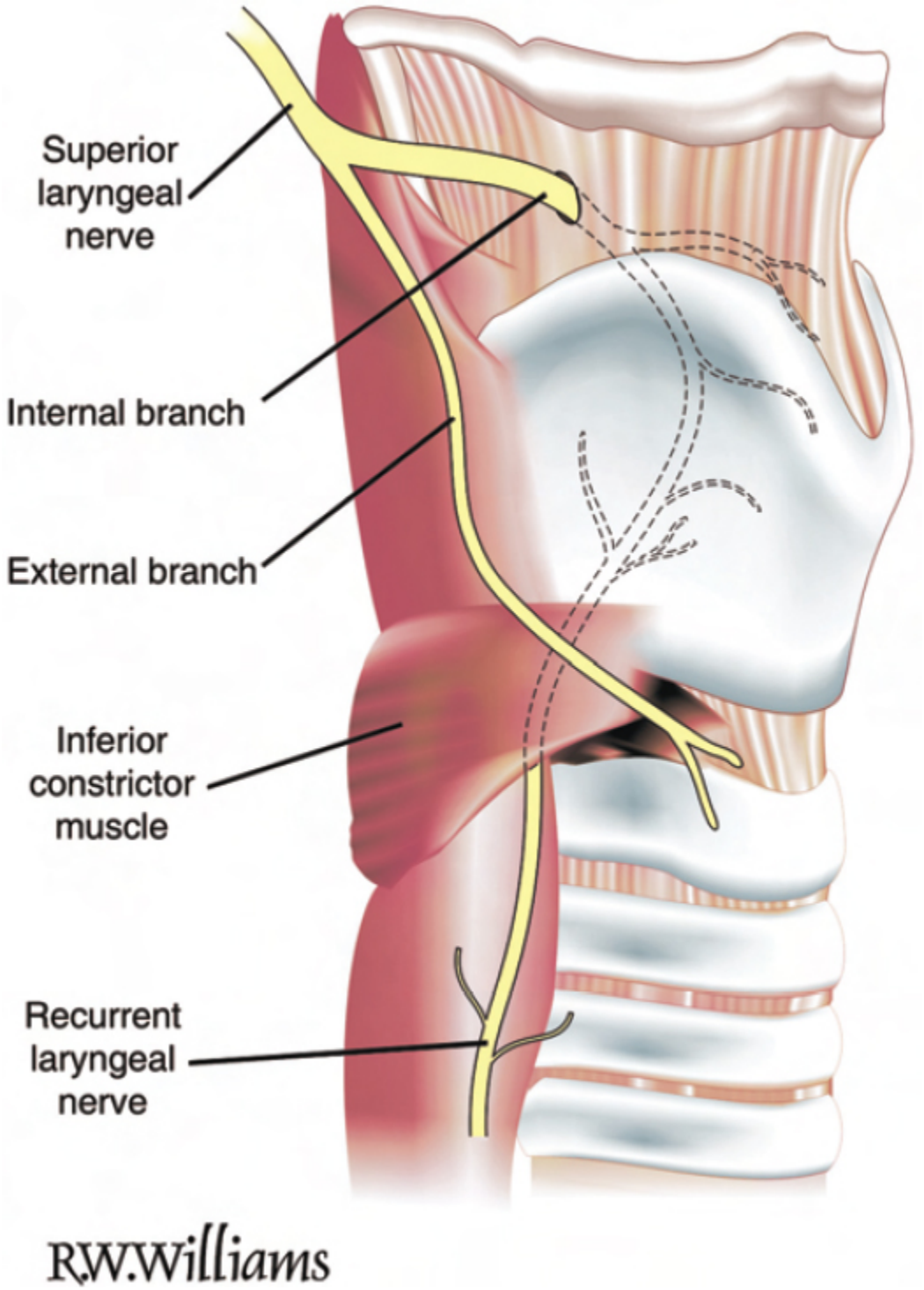

Figure 7.6: Oblique view of the larynx. Note how the internal branch of the superior laryngeal nerve pierces the thyrohyoid membrane midway between the hyoid bone and the superior border of the thyroid cartilage.

- The larynx is the most heavily innervated sensory structure in the body, followed closely by the carina. Stimulation of the unanesthetized

larynx during intubation causes reflex glottis closure (mediated by the vagus) and reflex sympathetic activation. Blood pressure (BP) and heart rate may as much as double as a result. This may lead to the elevation of intracranial pressure, particularly in patients with imperfect autoregulation; aggravate or incite myocardial ischemia in patients with underlying coronary artery disease; or incite or aggravate large vessel dissection or rupture (eg, penetrating injury to a carotid, thoracic aortic dissection, or rupture of an aneurysmal abdominal aorta).

- The pyramidal arytenoid cartilages sit on the posterior aspect of the larynx (Fig. 7.5). The intrinsic laryngeal muscles cause them to swivel, thereby opening and closing the vocal cords. An ETT that is too large may, over time, compress these structures, causing mucosal and cartilaginous ischemia and resultant permanent laryngeal damage. A traumatic intubation may dislocate these cartilages posteriorly (more often a traumatic curved blade–related complication) or anteriorly (more often a straight blade traumatic complication), which, unless diagnosed early and relocated, may lead to permanent hoarseness.
- The larynx bulges posteriorly into the hypopharynx, leaving deep recesses on either side called the piriform recesses or sinuses. Foreign bodies (eg, fish bones) occasionally become lodged there. During active swallowing, the larynx is elevated and moves anteriorly, the epiglottis folds down over the glottis to prevent aspiration, and the bolus of food passes midline into the esophagus. When not actively swallowing (eg, the unconscious patient), the larynx rests against the posterior hypopharynx such that a nasogastric (NG) tube must traverse the piriform recess to gain access to the esophagus and stomach. Ordinarily, an NG tube introduced through the right nostril passes to the left at the level of the hypopharynx and enters the esophagus through the left piriform recess. Similarly, with a left nostril insertion, the NG tube gains access to the esophagus through the right piriform recess.
- The cricothyroid membrane (CTM) extends between the upper anterior surface of the cricoid cartilage to the inferior anterior border of the thyroid cartilage. Its height tends to be about the size of the tip of the

index finger externally in both male and female adults. Locating the cricoid cartilage and the CTM quickly in an airway emergency is crucial. It is usually easily done in men because of the obvious laryngeal prominence (Adam's apple). Locate the laryngeal prominence, and then note the anterior surface of the thyroid cartilage immediately caudad, usually about one index finger's breadth in height. There is an obvious soft indentation caudad to this anterior surface with a very hard ridge immediately caudad to it. The soft indentation is the CTM, and the ridge is the cricoid cartilage. Because of the lack of a distinct laryngeal prominence in women, locating the membrane can be much more difficult. In women, place your index finger in the sternal notch. Then drag it cephalad in the midline until the first, and ordinarily the biggest, transverse ridge is felt. This is the cricoid ring. Superior to the cricoid cartilage is the CTM, and superior to that, the anterior surface of the thyroid cartilage, and then the thyrohyoid space and thyroid cartilage. The CTM is higher in the neck in women than it is in men because women's thyroid cartilage is relatively smaller than that of men. Localization of the CTM can also be performed using the linear probe on a bedside ultrasound and may be helpful when landmarks are indistinct.

- The CTM measures 6 to 8 mm from top to bottom. The proximity of the CTM to the vocal cords is also the driving factor in using small tracheal hooks during surgical cricothyrotomy to minimize any risk to the cords (see Chapter 19).

TRACHEA

The trachea begins at the inferior border of the cricoid ring. The sensory supply to the tracheal mucosa is derived from the recurrent laryngeal branch of the vagus nerve. The trachea is between 9 and 15 mm in diameter in the adult and is 12 to 15 cm long. It may be somewhat larger in the elderly. The adult male trachea will generally easily accept an 8.5-mm inner diameter (ID) ETT; a 7.5-mm ID ETT is preferable in women. If the patient being intubated requires bronchoscopic pulmonary toilet after admission (eg, chronic obstructive pulmonary disease and airway burns), consider increasing to a 9.0-mm ID tube for men and an 8.0-mm ID tube for women.

SUMMARY

Functional anatomy is important for expert airway management. Attention to the nuances and subtleties of anatomy in relation to technique will often mean the difference between success and failure in managing airways, particularly difficult airways. A clear understanding of the relevant anatomic structures, their blood supply, and their innervation will guide the choice of intubation and anesthesia techniques and will enhance understanding regarding the best approach to each patient. It also provides a basis for understanding how complications are best avoided, or if they occur, how they may be detected.

EVIDENCE

What anatomic nasal structures put a patient at risk of bleeding during nasal intubations, and how can it be mitigated?

Kiesselbach plexus (Little's area) is a very vascular area located on the anterior aspect of the septum in each nostril. Vasoconstrictors may help limit epistaxis and have the added benefit of increasing the caliber of the nasal chamber. Many vasoconstrictors exist including topical cocaine, oxymetazoline, and neosynephrine. Cocaine should be used with caution in patients with coronary artery disease as vasospasm has been reported.[1] Although there is no solid evidence that preparatory vasoconstriction is required prior to nasal intubation, it is common practice and may be helpful in some cases.[2]

What anatomic structure is susceptible to trauma during nasal intubation?

Although many structures can be damaged during nasal intubations, there exists a mucosal depression at the entrance of the eustachian tube in the posterior nasopharynx that can snag the tip of the ETT and precipitate mucosal trauma or dissection. Highest risk patients include those with chronic debilitating conditions. If this injury is suspected, antibiotics may be required to prevent infection or mediastinitis.[3–5]

What structural factors can complicate nasotracheal intubation?

Two other factors related to anatomy tend to be important when considering a nasotracheal intubation. First, the paranasal sinuses open into the nasal

canal and may be at risk for infection with prolonged nasotracheal intubation.[6] Second, the nasal passage is bound superiorly by the cribriform plate, and with suspected or known basilar skull fractures, damage to the cribriform plate may result in migration of nasal foreign bodies into the cranial vault.[7]

How are men and women different regarding CTM anatomy?

Subtle but important differences exist between the CTM in men versus women. First, the CTM is often higher, or more cephalad, in location as a result of a narrower thyroid shield. Second, the point of the upper thyroid cartilage is less prominent. As a result, anatomic localization can be more challenging.[8–10]

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Section II

Oxygenation and Ventilation

8 Principles of Peri-intubation Oxygenation
9 Non-Invasive Positive Pressure Ventilation and High-Flow Nasal Oxygen
10 Mechanical Ventilation
11 Oxygen and Carbon Dioxide Monitoring

CHAPTER 8

Principles of Peri-intubation Oxygenation

Robert F. Reardon

Brian E. Driver

INTRODUCTION

Hypoxemia during emergency airway management is a feared complication and is associated with dysrhythmias, hypoxic brain injury, and cardiac arrest. Critical hypoxemia often occurs when clinicians focus primarily on laryngoscopy and tube placement rather than gas exchange and oxygenation. Hypoxemia could be avoided in many cases by meticulous preoxygenation, which is the delivery of oxygen before intubation with the goal to replace all alveolar nitrogen with oxygen. This creates an oxygen reservoir that patients can utilize while they are not breathing. Unfortunately, the principles of preoxygenation are often poorly understood and applied.

Robust preoxygenation and the ability to reoxygenate patients with bag-mask ventilation if the first intubation attempt fails are the most important aspects of safe emergency airway management. The main goal of airway management is gas exchange. Although gas exchange can be accomplished with mechanical ventilation after successful placement of an endotracheal tube, it is much more important to prevent hypoxemia throughout the intubation procedure.

Rapid sequence intubation (commonly known as RSI, with details in Chapter 20) is the most common method for emergency airway management and causes the patient to be apneic while laryngoscopy and tube delivery are performed. Apnea is acceptable provided the patient maintains a normal oxygen saturation. Optimal preoxygenation prolongs the

period of safe apnea time, which is the time from the onset of apnea from induction until the patient experiences an oxygen saturation below 90%. Safe apnea time varies from several seconds to several minutes, depending on the patient's body habitus, comorbidities, acuity of illness, oxygen consumption, and oxygen reservoir created through preoxygenation efforts (**Fig. 8.1**). A longer safe apnea time allows for unrushed and methodical laryngoscopy and endotracheal tube placement. Conversely, attempts at intubation can feel rushed and frantic when oxygenation levels start to fall. If preoxygenation is not performed, the stress of placing the tube correctly before critical hypoxemia ensues can transform what might have been a routine intubation into one complicated by uncertainty and poor technique, even in the hands of skilled and experienced clinicians.

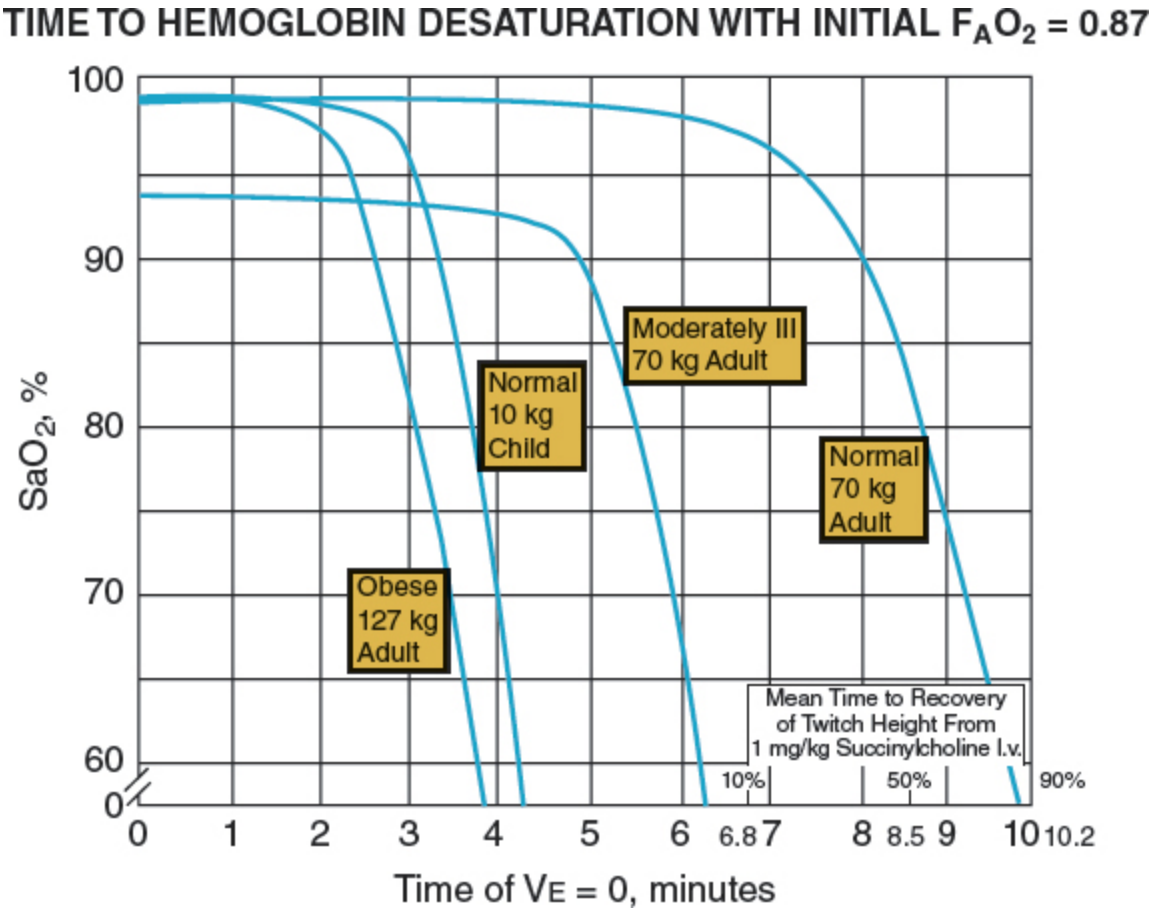

Figure 8.1: Time to desaturation is affected by many factors, including underlying medical conditions, age, body habitus, and how well preoxygenation is performed. All patients requiring emergency intubation should be assumed to be at risk for rapid desaturation, and should have maximal preoxygenation. (From Benumof JL, Dagg R, Benumof R. Critical

hemoglobin desaturation will occur before return to an unparalyzed state following 1 mg/kg intravenous succinylcholine. *Anesthesiology*. 1997;87(4):979-982.)

In this chapter, we will describe best-practice preoxygenation techniques, including patient positioning, oxygen delivery, noninvasive positive pressure ventilation (NPPV), and apneic oxygenation. The goal of preoxygenation is to maximize safe apnea time, which facilitates calm and confident intubation success without hypoxemia. However, we will also discuss when to abandon passive techniques and take control of ventilation and oxygenation with active bag-mask ventilation and rescue oxygenation.

PRINCIPLES OF PREOXYGENATION

The goal of preoxygenation is to establish a reservoir of oxygen within the lungs by replacing mixed alveolar gases—mostly nitrogen—with oxygen. The volume available for this oxygen reserve is defined by the patient's functional residual capacity, which is ~30 mL/kg in adult patients. This provides a source of oxygen that the pulmonary circulation can draw from even after the patient is not breathing. Ideally, complete pulmonary denitrogenation is achieved, and, if measured, the fraction of expired oxygen (also known as FeO_2, or ETO_2 if measured breath-by-breath, and is defined as the proportion of exhaled gas that is oxygen) would be near 90% (never 100% because of exhaled CO_2 and water vapor). In patients with healthy lungs, preoxygenation can be maximized by having the patient breathe 100% oxygen for 3 to 5 minutes. Alternatively, cooperative patients with healthy lungs can be preoxygenated by having them perform eight maximal volume deep breaths while breathing 100% oxygen. Clinicians must understand the differences in the fraction of inspired oxygen (FIO_2) provided by commonly used oxygen delivery systems (**Table 8.1**). Preoxygenation is best accomplished with patients in the sitting or head-up position. Patients with lung pathology and decreased functional residual capacity may require positive pressure for maximal preoxygenation. The details and rationale for these techniques are described in the following sections.

TABLE 8.1 Low FIO_2 Oxygen Delivery Techniques (Inadequate for Preoxygenation)

System	Source O_2 Flow Rate (L/min)	Fio_2 (Approximate) (%)
Nasal cannula	2-4	30-35
	6	40
Simple face mask	6	45
	10	55
Venturi mask	15	50
Non-rebreather mask	15	70
Bag-valve mask with mask leak or without one-way exhalation valve	15	<50

Although the gas flowing from each device is 100% oxygen at any flow rate, the oxygen content of each inhaled breath is much lower than this (FIO_2 30%-70%) for devices and flow rates listed in this table because either the patient's inspiratory flow rate exceeds the delivered oxygen flow rate or a mask leak is present.

FIO_2, fraction of inspired oxygen.

Maintain an Upright Position for Optimal Preoxygenation

Regardless of how preoxygenation is performed, the patient should be situated in an upright position to maximize the effectiveness of preoxygenation. The oxygen storage capacity of the lungs is greatest when patients are in the upright position and lowest in the supine position, and multiple studies have confirmed that preoxygenation is significantly more effective in an upright position. This allows full utilization of a patient's functional residual capacity. The functional residual capacity is a potential space, rarely used during normal tidal breathing, but recruited during preoxygenation to store oxygen that can be used by the pulmonary circulation to maintain oxygenation during apnea. Those who cannot tolerate the upright position (eg, those with spinal precautions) should be preoxygenated in a reverse Trendelenburg position. Upright or head-up positioning during preoxygenation is especially important in obese patients, who are prone to rapid desaturation during apnea, and in patients whose abdominal mass further reduces the size of the functional residual capacity (**Fig. 8.1**).

High-Concentration Oxygen Delivery Versus Traditional Supplemental Oxygen

There are widespread misconceptions about the F_{IO_2} supplied by common oxygen delivery devices. Optimal preoxygenation requires delivery of 100% F_{IO_2}, but common oxygen delivery methods do *not* provide 100% F_{IO_2} (**Table 8.1**). Although the oxygen flowing from the tubing is 100% oxygen, not all the air inhaled by the patient is oxygen because the patient's inspiratory flow rate exceeds the delivered oxygen flow rate. The primary limitation with traditional oxygen delivery is the low oxygen flow rate used (15 L/min or less) and the presence of significant mask leaks. Note that the bag-valve mask (BVM) and non-rebreather mask are *both* listed in Table 8.1 as inadequate for preoxygenation if improper technique or inadequate oxygen flow is used.

However, both the BVM and non-rebreather mask can provide 100% F_{IO_2} with proper technique (**Table 8.2**), principally by ensuring a tight mask seal and one-way valves are present when using a BVM, and by using very high oxygen flow rates with a non-rebreather mask. In theory, a non-rebreather mask could provide 100% F_{IO_2} at low flow rates if the mask seal was tight and the one-way valves were functioning. However, the vast majority of commercially available non-rebreather masks have neither of these characteristics.

TABLE 8.2 High F_{IO_2} Oxygen Delivery Techniques

System	Source O_2 Flow Rate (L/min)	F_{IO_2} (Approximate) (%)
Non-rebreather mask	≥40	100
Simple mask[a]	≥40	70–90
Bag-valve mask with one-way valve and no mask leak	15	100
High-flow nasal cannula	40–60	100
NPPV machine	Wall O_2, >50 L/min	100
Anesthesia machine (flush valve open)[b]	30–35	100

[a]*FIO_2 is less predictable with simple masks because of room air entrainment and turbulent flow.*

[b]*High-flow flush compensates for a mask leak.*

These non-rebreather mask shortcomings, when low oxygen flow is used, result in inadequate preoxygenation because the patient breathes in large amounts of room air, which lowers the overall FIO_2. This is because patients typically have inspiratory flow rates higher than the set flow rate of 15 L/min, and some patients breathe at a higher minute ventilation than the total oxygen delivered over one minute. This means that even if the patient breathes in every molecule of oxygen delivered from the device during each inhalation phase, each inhalation still contains a substantial amount of room air. Thus, FIO_2 decreases as the patient's minute ventilation and inspiratory flow increase, because the ventilatory demands of the patient are higher than the oxygen delivery provided by the device, and room air makes up the difference.

When high flow rates are used, which is easily accomplished with standard equipment by opening a standard flow meter to the "flush" rate (~50 L/min), it is possible to overcome the limitations of a non-rebreather mask and deliver an FIO_2 closer to 100%. Table 8.2 lists systems and accompanying flow rates that can deliver high FIO_2 in the setting of high minute ventilation and inspiratory flow, and, for some devices, regardless of mask seal. The key is to deliver 100% oxygen at a flow rate well above the patient's inspiratory needs so that room air volume is not required to satisfy the patient's inspiratory effort. The oxygen flow rate is likely more important than the oxygen delivery device. Although high flow rates are noisy, they allow delivery of high-concentration oxygen using a non-rebreather face mask or nasal cannula. In addition, very high oxygen flow rates create a small amount of positive end-expiratory pressure (PEEP), which may modestly improve alveolar recruitment and preoxygenation efforts.

Preoxygenation With and Without Positive Pressure

Patients without underlying respiratory pathology generally do not require positive pressure to achieve adequate preoxygenation. The simplest method

to perform preoxygenation for these patients is using a non-rebreather mask at a high flow rate (40 L/min or more).

Patients with hypoventilation; morbid obesity; shunt physiology from pneumonia, atelectasis, or other pathology; and those who do not achieve an oxygen saturation >93% after attempted preoxygenation with a source delivering high-flow oxygen should receive positive pressure preoxygenation, most commonly delivered with the use of noninvasive positive pressure. Some clinicians prefer to use a BVM device with a PEEP valve for spontaneously breathing patients; this approach, though theoretically sound, is difficult because it requires maintenance of a perfect mask seal throughout preoxygenation, a task that is difficult to accomplish.

OXYGEN DELIVERY DEVICES

This section will detail the benefits and drawbacks of various oxygen delivery devices. The devices themselves, as seen in Tables 8.1 and 8.2, do not determine the effectiveness of preoxygenation. The effectiveness of a device depends substantially on the flow rate of oxygen, and, for some devices, the tightness of the mask seal and other technical factors.

Low-Flow and High-Flow Nasal Oxygen

Low-flow nasal cannula is often the first line of oxygen supplementation and is appropriate in patients with mild hypoxemia. Common initial flow rates are 2 to 4 L/min. A traditional teaching is that the maximal effective flow rate for nasal cannula oxygen is 6 L/min, which delivers a maximal F_{IO_2} of 35% to 40%. Low-flow nasal cannula cannot be used as a primary preoxygenation method.

In the last several years, oxygen delivery by high-flow nasal oxygen (HFNO) has become common. Commercial HFNO systems (eg, Optiflow, Vapotherm, Comfort Flo) provide nearly 100% F_{IO_2} by using flow rates of 30 to 70 L/min through larger caliber tubing. They also heat and humidify the oxygen, making the high flow rate more tolerable for the patient. HFNO washes out the upper airway dead space and fills it with oxygen, reduces work of breathing by providing adequate flow, and creates a flow-dependent increase in end-expiratory lung volume that mimics PEEP.

HFNO systems have been successfully used to support patients in hypoxemic respiratory failure, and available evidence suggests HFNO is a useful tool for preoxygenation when compared to low-flow non-positive pressure systems. If available, HFNO is a very reasonable and effective method of preoxygenation.

There have been two small intensive care unit (ICU) studies comparing HFNO to NPPV, with noninvasive positive pressure showing modestly lower rates of oxygen desaturation. How HFNO compares to NPPV in the emergency department (ED) setting is not yet clear.

Simple Face Mask

A simple face mask is a non-form-fitting plastic mask that covers the nose and mouth. It does not have an external bag reservoir, so the volume of oxygen available for each breath at low oxygen flow rates is only the volume contained within the mask (~100-150 mL) plus the oxygen delivered while inhalation occurs. Traditionally, a simple face mask was used with flow rates between 4 and 10 L/min. At these low flow rates, the F_{IO_2} is highly variable and is dictated by the patient's respiratory pattern and the volume of room air drawn in from around the mask. The traditional teaching was that the maximal F_{IO_2} that could be delivered by a simple face mask is ~50%, when an oxygen flow rate of 15 L/min is used. However, F_{IO_2} values of 90% and higher can be delivered by a simple face mask when the source oxygen flow rate is set to a higher level (≥40 L/min). Some experts believe that a simple face mask with a high flow rate (≥40 L/min) is a reasonable way to provide maximal preoxygenation prior to emergency RSI (see the "Evidence" section) in patients without airspace disease. However, it is more prudent to use a non-rebreather mask for two reasons. First, the most common simple mask (made by Hudson DCI) has small holes adjacent to where the oxygen tubing connects to the mask; with very high oxygen flow rates, the Venturi effect will draw room air into the mask next to the oxygen stream and dilute the F_{IO_2} (**Fig. 8.2A**). Second, very high flow rates cause turbulence near the side holes in the mask and room air is unpredictably entrained, which provides lower F_{IO_2} than expected for a given flow rate. Most non-rebreather masks do not have these limitations.

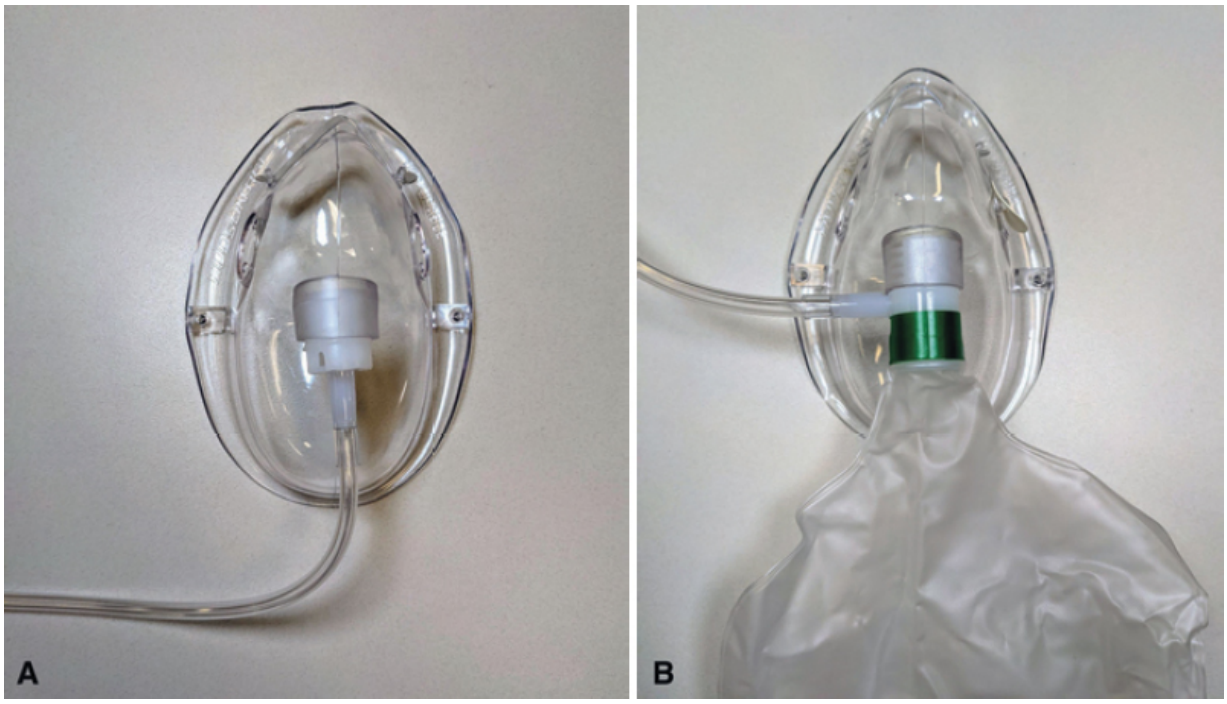

Figure 8.2: A: Simple (Hudson) facemask. This mask delivers an F_{IO_2} of about 50% with an oxygen flow rate of 15 L/min and an F_{IO_2} of about 70% with an oxygen flow rate ≥40 L/min. Note the open side ports and a small hole in the white plastic adjacent to where the oxygen tubing connects, which likely entrains room air into the system via the Venturi effect. Also, turbulent flow near the side ports causes unpredictable amounts of room air entrainment. B: Non-rebreather mask. This mask delivers an F_{IO_2} of about 70% with a standard oxygen flow rate of 15 L/min, but can provide an F_{IO_2} of 100% with flush flow rate of ≥40 L/min.

Non-rebreather Mask

A non-rebreather mask is a simple face mask with a 500 to 1000 mL reservoir bag from which the patient can draw 100% oxygen during inspiration. Most non-rebreather masks also contain one or two crude one-way valves on the side of the mask, which are supposed to open during expiration and close during inspiration, limiting entrainment of room air into the system. Non-rebreather masks are excellent preoxygenation devices, provided they are used properly.

To achieve a high F_{IO_2} with a non-rebreather mask at low flow rates, there must be a good mask seal, the one-way valves must be present and functioning properly, and all inspired air must come from the reservoir bag. In practice, there is a poor mask seal, inconsistent function of the one-way valves, and entrainment of room air with inspiration from around the mask,

which limits its efficacy (**Fig. 8.2B**). Therefore, at low flow rates a non-rebreather performs poorly for preoxygenation, which has been confirmed in multiple studies that have shown non-rebreather masks with an oxygen flow rate of 15 L/min deliver a maximal F_{IO_2} of 65% to 70%.

However, the use of high oxygen flow rates with non-rebreather masks overcomes the limitations of the imperfect mask seal and crude one-way valves, because the flow rate of the delivered oxygen exceeds the inspiratory demands of the patient. Multiple studies have confirmed that using a non-rebreather mask with a very high source oxygen flow rate (flush rate ≥ 40 L/min) delivers an F_{IO_2} close to 100% (see "Evidence" section). This is an excellent system for providing high-concentration oxygen for preoxygenation before emergency RSI. Although the reservoir bag is probably not helpful in most patients, it has a theoretical benefit in patients with extremely high minute ventilation.

The benefit of a non-rebreather mask is its ease of use; it is simply placed on the patient and the flow rate is turned up as high as it will go. There is no need to attempt to create a tight mask seal.

How to Deliver High-Flow Oxygen With Standard Flowmeters

Standard wall-mounted oxygen flowmeters, with gradations on the glass cylinder up to 15 L/min, typically have a different maximum flow rate stamped on the metal body, also known as the flush flow rate. The flush flow rate is typically 40 L/min or more (**Fig. 8.3A**). To achieve the flush flow rate, simply turn the oxygen flowmeter knob until it does not turn further; the high flow of oxygen will be easily audible. This enables delivery of nearly 100% F_{IO_2} with a non-rebreather mask. Alternatively, there are commercially available oxygen flowmeters that allow flow rates up to 70 L/min (**Fig. 8.3B**).

MEDICAL
O2
ATTENTION
Max Flush
Flow
90 LPM
ATTENTION
Max Flush
Flow Range
40-60 LPM
A

YGEN

Figure 8.3: A: Flush rate labels on standard oxygen flowmeters. The maximum flow rate for oxygen flowmeters, known as the "flush" rate, is typically marked on the side of the device. Standard flowmeters that show a maximum gradation of 15 L/min at the top of the clear cylinder are usually able to deliver oxygen at >40 L/min. B: Standard and high-flow oxygen flow meters. On the left is a standard flow meter (0-15 L/min, with a "flush rate" of 40-60 L/min). On the right is a high-flow meter (0-70 L/min, with a flush rate of 90 L/min).

Occasionally, a standard oxygen wall source will have a maximum flow < 40 L/min, which can be discovered by reading the marked maximum rate on the body of the flowmeter, or by listening to the flow of oxygen when the flowmeter is maximally open. Flow rates > 40 L/min are loud and easily heard; flow rates closer to 15 L/min are quieter. Find a different oxygen source capable of higher flow rate if a low-flow oxygen source is discovered where intubation is about to occur.

Achieving high flow rates depends on adequate oxygen pressure within the oxygen delivery lines throughout a hospital or ambulance—typically a pressure of ~50 lb/in^2. Most hospitals that routinely deliver mechanical ventilation will have adequate oxygen pressure because ventilators and NPPV also require a similar pressure. If a hospital has inadequate oxygen

stores or inadequate oxygen pressure—a rare circumstance—they will be unable to administer flush rate oxygen.

Bag-Valve Mask

BVM devices can provide 100% FIO_2 during active positive pressure ventilation in apneic or nearly apneic patients when the mask seal is tight. This is their main purpose. Although squeezing the bag in synchrony with patient inspiration is commonly performed for preoxygenation and is believed to augment oxygen delivery to spontaneously breathing patients, this practice should be avoided. Squeezing in near synchrony is technically difficult, provides minimal positive pressure (1-2 cm H_2O), requires additional attention paid to the patient's respiratory cycle, and performs similarly to creating a tight mask seal without bagging. If a spontaneously breathing patient truly needs positive pressure for preoxygenation, a noninvasive positive pressure machine should be used when time permits.

BVMs may be used for spontaneously breathing patients without bagging; however, the degree of negative inspiratory force (NIF) required to open the one-way inspiratory valve is variable and may be more than the patient can generate depending on their size, age, diaphragmatic strength, and presence of preexisting lung disease. The effort required to overcome the inspiratory resistance will also vary based on the bag's valve configuration. If there is insufficient ventilatory effort, this approach could, in essence, suffocate the patient and should be avoided. In addition, to achieve FIO_2 levels of more than 90%, there also needs to be near-perfect mask seal and function of the one-way exhalation valve (intrinsic to the device or with the addition of a PEEP valve). The mask can simply be held with a tight seal and the patient breathes normally, taking in 100% oxygen from the bag reservoir.

If the mask seal is compromised, the patient will draw in room air around the mask during inspiration and significantly lower the FIO_2. In spontaneously breathing patients with enough NIF to draw in their required volumes, preoxygenation with a BVM and a good mask seal is better than a non-rebreather mask at standard 15 L/min flow rates, but similar to a non-rebreather mask at high flow rates.

Using high flow rates (≥40 L/min) with a BVM device with a tight mask seal provides identical oxygen F_{IO_2} (100%) as a BVM with low flow rates for most patients, provided the patient does not have extreme tachypnea, large tidal volumes (approximately >1000 mL), or a minute ventilation >15 L/min, in which case the bag will entrain room air and the F_{IO_2} will accordingly decrease.

Irrespective of the set flow rate for a BVM, there is little oxygen delivered if a mask leak is present, in which case the patient will breathe room air; this is because BVMs have inspiratory valves that open only with sufficient positive or negative pressure—oxygen is delivered only if the bag is squeezed or the patient creates enough negative pressure with inhalation to open the valve. If there is not a tight mask seal, the patient cannot generate enough negative pressure within the mask to open the inspiratory valve, and little to no oxygen flows from the mask.

Clinicians who perform emergency airway management must understand that BVM devices have important differences between different manufacturers and models. As mentioned earlier, a crucial feature is whether a one-way exhalation valve is present and functioning. Without one, BVMs deliver mostly room air (**Fig. 8.4**) to spontaneously breathing patients. If a PEEP valve is added, this serves as a one-way valve while also adding PEEP. PEEP is beneficial if the patient requires positive pressure ventilation, but PEEP is only maintained if a *perfect* mask seal is held *at all times*. Preoxygenation of these patients with a BVM and a PEEP valve has been proposed, but has not been well studied and probably not a good substitute for NPPV.

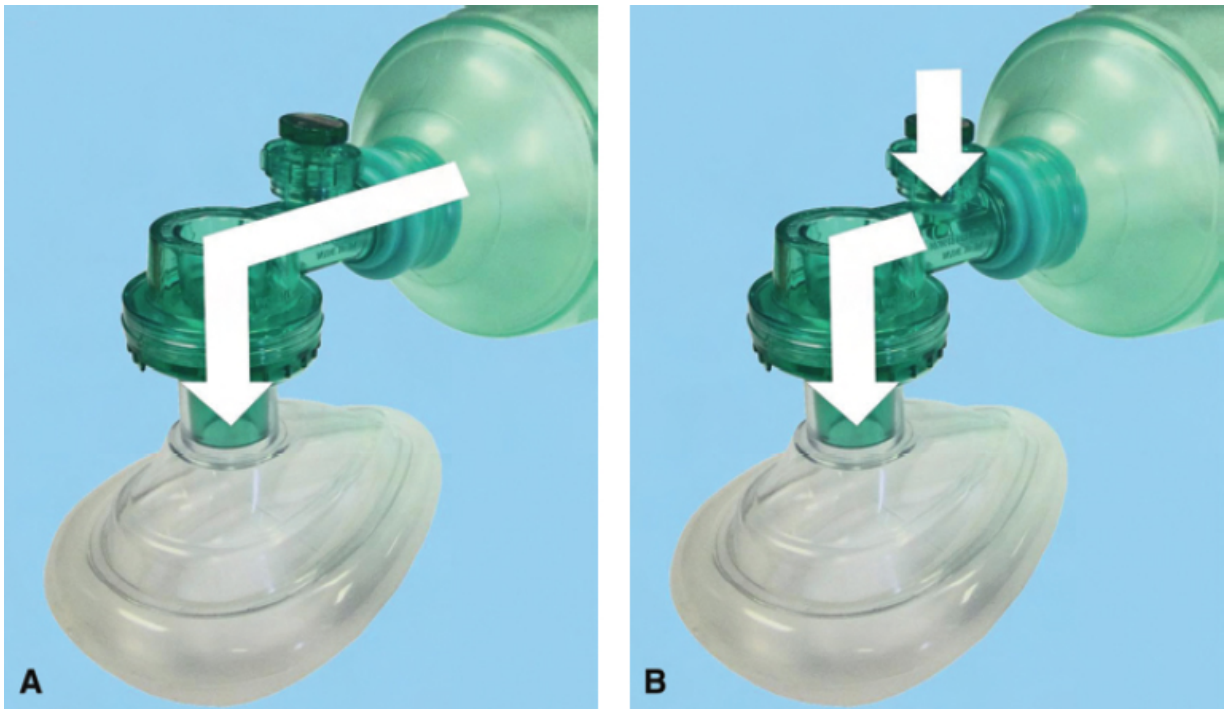

Figure 8.4: A: Resuscitation bag used with positive pressure (when bag is being squeezed) and no active breathing by the patient. Regardless of whether a one-way exhalation valve is present, the patient receives 100% oxygen from the bag reservoir, as long as the mask seal is effective. B: Resuscitation bag during spontaneous breathing (when bag is *not* being squeezed) without a one-way exhalation valve. The exhalation port between the bag and mask is open to room air. When the patient inhales, a large amount of room air (oxygen concentration 21%) is entrained from the exhalation port into the tubing and then inhaled by the patient. Some air from the reservoir bag is also inhaled. This results in an inhaled F_{IO_2} as low as 30%. If a one-way exhalation valve is added (not pictured), such as a positive end-expiratory pressure valve, room air can no longer enter the tubing and the patient breathes 100% oxygen from the bag reservoir.

Venturi Mask

Venturi masks are traditionally referred to as “high-flow” supplemental oxygen devices, but in fact do not provide high flows of oxygen and should not be considered a device able to provide a high concentration of oxygen. Venturi masks are designed to be used with source oxygen flow rates of 12 to 15 L/min and can deliver air with 24% to 50% oxygen. The principal benefit of Venturi masks is their ability to provide consistent F_{IO_2} by fixing the degree of room air entrainment and should be considered “precision control” oxygen delivery devices rather than high-flow devices. They should not be used for preoxygenation and are most helpful when titratable

amounts of oxygen are important or when there is concern about excessive oxygen administration, as in patients with chronic obstructive pulmonary disease.

Noninvasive Positive Pressure Ventilation for Preoxygenation

Patients with underlying lung pathology usually require positive pressure ventilation to achieve maximal preoxygenation. Examples include those with pulmonary edema, severe pneumonia, and acute respiratory distress syndrome, and those with compressive atelectasis, such as late term pregnancy, large volume abdominal ascites, and morbid obesity. These patients have alveoli that are perfused but not ventilated or have high intrinsic airway pressures that confound preoxygenation efforts and need increased airway pressure to open alveoli for maximal oxygen storage and optimal gas exchange. Therefore, these at-risk patients should be preoxygenated upright with NPPV whenever possible (see Chapter 3 for more information).

When using NPPV, it is best to provide both inspiratory and expiratory pressure support. This can be accomplished using the bilevel positive airway pressure (BiPAP) mode on a noninvasive machine or a standard ventilator with pressure support plus PEEP. Alternatively, positive airway pressure can be applied using a disposable continuous positive airway pressure (CPAP) mask setup or a PEEP valve attached to a standard BVM device. Delivery of bilevel positive pressure using a specialized NPPV machine is probably the best default technique because these machines compensate for mask leaks. Delivering an end-expiratory pressure of 5 to 10 cm H_2O and an inspiratory pressure of 10 to 15 cm H_2O are good starting points in most cases (see Chapter 9 for more about NPPV).

OTHER PREOXYGENATION CONCEPTS

Monitoring the Effectiveness of Preoxygenation Using End-Tidal OXYGEN

Some commercially available vital sign monitors accept modules that can measure end-tidal oxygen (ETO_2) values, in much the same way that end-tidal carbon dioxide is measured. Two small studies have examined the use of ETO_2 during preoxygenation in the ED, finding that monitoring this value may be a useful method to ensure that most of the pulmonary nitrogen has been replaced with oxygen. The goal ETO_2 is 85% or greater. Most patients in the studies received preoxygenation with a BVM, and the most common change to preoxygenation to optimize ETO_2 was improving the BVM mask seal. Other changes included increasing the duration of preoxygenation, increasing the flow of oxygen, and switching from a non-rebreather mask to a BVM. Therefore, ETO_2 monitoring seems most beneficial when a BVM is used for preoxygenation, as this technique requires constant attention to the mask seal. Please see Chapter 11 for further details.

Concept of Delayed Sequence Intubation to Facilitate Preoxygenation

Delayed sequence intubation is not a change in how RSI medications are delivered, as the name implies, but is a form of procedural sedation to facilitate patient compliance with preoxygenation, which would otherwise be impossible because of patient agitation. Often employed for agitated or delirious patients, the goal is to administer a sedative agent, such as ketamine, at a dose that is unlikely to affect the patient's respiratory drive or protective airway reflexes while providing enough sedation so that the patient accepts NPPV or high-flow oxygen by face mask. If this technique is employed, it is prudent to start at a low dose and administer more if this dose is ineffective. After preoxygenation is completed, standard RSI medications are administered.

Delayed sequence intubation is not well studied, and its core evidence base consists of a single case series of expert clinicians using this technique in a convenience sample of patients. Given the paucity of evidence supporting its safety in a broader group of clinicians, this procedure should be undertaken with great caution because sedation of critically ill and decompensated patients may result in respiratory depression, arrest, or

inability to protect their airway. If this technique is to be attempted, the airway manager needs to be fully prepared for immediate definitive airway management (see Chapter 20 for more details).

Apneic Oxygenation

Apneic oxygenation is the administration of oxygen during the apneic period of RSI, usually applied via a standard nasal cannula with a flow rate of 5 to 15 L/min. Because oxygen diffuses across the alveoli more readily than carbon dioxide and has a high affinity for hemoglobin, more oxygen leaves the alveoli than carbon dioxide enters during apnea. This creates a gradient that causes oxygen to travel from the nasopharynx to the alveoli and into the bloodstream by a physiologic principle known as "aventilatory mass flow." Except for a "forced to act" scenario, during which preoxygenation is not possible because of the immediacy of tube placement, apneic oxygenation should be considered for every tracheal intubation because it may decrease the risk of severe hypoxemia, especially if laryngoscopy is prolonged—which is sometimes difficult to predict.

To perform apneic oxygenation, a standard nasal cannula is placed beneath the main preoxygenation device. If the patient is awake, the flow rate should be as high as the patient can tolerate during the preoxygenation phase, typically between 5 and 15 L/min. If the patient is comatose or unresponsive, the nasal cannula can be set to 15 L/min or higher. When the preoxygenation mask is removed for intubation, the nasal cannula remains in place. During intubation attempts, the nasal cannula should be set to at least 15 L/min. If there is nasal obstruction, a nasopharyngeal airway can be placed in one or both nares to facilitate oxygen delivery to the posterior nasopharynx. To optimize gas flow past the upper airway, the patient should be ideally positioned for tracheal intubation, and a jaw thrust should be performed to ensure upper airway patency.

Multiple studies in the operating room setting have shown that apneic oxygenation increases safe apnea time, especially in obese patients. Recent randomized trials in the ICU and ED showed no benefit of apneic oxygenation after optimal preoxygenation. Rather than demonstrating the futility of apneic oxygenation for all patients, these trials demonstrate that apneic oxygenation does not provide benefit to the average patient who is

rapidly intubated after adequate preoxygenation. Apneic oxygenation, instead, is meant to help patients with prolonged laryngoscopy, more rapid desaturation, or an inadequate pulmonary reservoir. It is uncertain what the results of a randomized trial would be that included only higher risk patients or those with prolonged laryngoscopy, but it seems probable that apneic oxygenation is much more likely to be beneficial for certain subgroups of patients undergoing emergency intubation.

In addition, a recent observational ED study on apneic oxygenation demonstrated an increase in first attempt intubation success without hypoxemia (see “Evidence” section). With an intervention as simple and inexpensive as nasal cannula, we recommend routine use of apneic oxygenation.

Bagging During the Apneic Period

RSI has traditionally been a non-ventilating procedure with no active ventilation during the apneic period of RSI. A recent randomized trial of 401 ICU patients challenged this practice by demonstrating higher average oxygen saturation, less frequent hypoxemia, yet similar rates of aspiration when bag-mask ventilation is performed during the apneic period. There was no sign that this practice is detrimental; however, this practice has not yet been validated in the ED setting and these data are difficult to extrapolate to emergency patients for several reasons. First, because these were ICU patients, it is likely they were more fasted than the typical ED patient needing intubation. In addition, patients deemed to be at high risk for aspiration were excluded from the study and no standardized preoxygenation strategies were defined or followed. Therefore, we do not know whether this practice is safe for all RSIs performed in the ED; however, it seems reasonable to do a risk-benefit analysis and provide gentle, controlled bag-mask ventilation during the apneic period to patients at risk for rapid desaturation but not at a high risk of aspiration. Additionally, all patients with an oxygen saturation <93% at the time of RSI medication administration, who are at very high risk of developing critical hypoxemia, should receive bag-mask ventilation during the apneic period, regardless of aspiration risk. Clinicians should recognize that facemask bagging will likely cause some degree of gastric insufflation. However, this

is not likely to cause harm if the bagging period is brief, but if prolonged bagging is required, there is more risk of passive regurgitation and aspiration. Applying cricoid pressure during facemask bagging might decrease the amount of gastric insufflation, but it is also known to prevent adequate ventilation (see Chapter 12).

Rescue Oxygenation

When the oxygen saturation decreases to 93% or lower, or when an intubation attempt fails, efforts should be focused on ventilation and oxygenation rather than persisting with the intubation attempt. Optimal bag-mask ventilation with a well-fitting mask and perfect technique is the first-line procedure for ventilation and reoxygenation in this scenario. The goal is to increase the oxygen saturation as high as possible (ideally 100%) and re-perform preoxygenation to allow continued safe apnea time for subsequent intubation attempts.

There is a delay of about 30 seconds between the onset of adequate bag-mask ventilation and an increase in oxygen saturation as measured by a pulse oximeter. Knowledge of this delay can ease anxiety felt by the intubator and the team members caring for the patient while mask ventilation is performed. High-quality bag-mask ventilation must be provided (see Chapter 12), as measured by chest rise, auscultation, and waveform capnography. The ability to provide high-quality bag-mask ventilation is an underestimated and difficult skill, and many emergency airway clinicians perform this procedure incorrectly. Practicing and optimizing bag-mask ventilation skills saves lives and significantly decreases the anxiety associated with emergency airway management.

Patients with difficult bag-mask ventilation because of head-and-neck radiation changes, poor mask seal (eg, beard, facial trauma), obesity, or other factors may be good candidates for an extraglottic device. Extraglottic devices are easy to insert and provide adequate ventilation and oxygenation in nearly all patients regardless of the experience of the clinician. In this scenario, the extraglottic device can be used like bag-mask ventilation: to temporarily provide ventilation and oxygenation until the oxygen saturation rises. The extraglottic device is then removed, and further intubation

attempts can proceed. The extraglottic device can also be used as a conduit for blind or flexible endoscopic intubation (see Chapter 13).

SUMMARY

Preoxygenation creates a pulmonary oxygen reservoir which increases safe apnea time during RSI. Traditional methods of supplemental oxygen delivery are inadequate for preoxygenation. The keys to preoxygenation are understanding how to deliver high-concentration (≈100%) oxygen, using appropriate flow rates, apneic oxygenation, ensuring proper head-up positioning, and knowing when to use positive pressure ventilation and rescue bag-mask ventilation.

EVIDENCE

What is the best way to preoxygenate for RSI?

If the patient has no underlying pulmonary pathology, using a non-rebreather at flush rate oxygen (>40 L/min) or a BVM at 15 L/min with a tight seal both provide excellent preoxygenation.[1,2] If the patient requires positive pressure ventilation because of obesity or shunt physiology from underlying pulmonary pathology, a noninvasive positive pressure machine should be used.

The historical gold standard for delivering 100% F_{IO_2} before intubation is use of an anesthesia machine with a well-fitted mask; however, both a BVM and a non-rebreather mask with flush rate oxygen have been shown to be equivalent to an anesthesia machine. A recent study by Groombridge et al compared several common preoxygenation methods to an anesthesia circuit and found that only the BVM (with a one-way exhalation valve) device was comparable.[2] However, in that study, the flow rate used for the simple mask and non-rebreather mask was just 15 L/min. Using a non-rebreather and increasing the flow rate to >40 L/min, achieved with a standard flowmeter knob rotated until it will not rotate further, has been shown to achieve similar preoxygenation as a BVM with 15 L/min of oxygen flow.[1,3] The benefit of using a non-rebreather mask at high flow rates is that no specialized equipment is required and the team does not need to constantly maintain a tight mask seal—this allows personnel to

attend to other important tasks during the preintubation period. A non-rebreather mask is preferred to the simple mask because of concerns with room air entrainment via the Venturi effect and turbulent flow.

BVM devices only provide 100% F_{IO_2} if a functioning one-way valve is present on the exhalation port and a good mask seal is constantly maintained. Many BVM devices do not have one-way valves,[4-6] which causes delivery of air with oxygen content similar to room air when used with spontaneously breathing patients. Also, bag-mask ventilation is a hands-on technique that requires the full attention of at least one team member; furthermore, many patients who need emergency airway management do not tolerate a tight mask seal and have insufficient inspiratory force to draw adequate volume from the reservoir. If a mask leak is present there is little oxygen delivered, resulting in very poor preoxygenation.[7] BVMs are primarily reserved for patients who require active bagging either in between attempts during RSI or in the preintubation period when significant hypopnea or apnea is manifest.

Patients should be in the upright or head-up position during preoxygenation whenever possible. Several randomized studies of both obese and nonobese patients have shown that preoxygenation in the upright or 20° to 25° head-up position significantly increases safe apnea time.[8-12]

Patients who are hypoxemic (oxygen saturation <93%) despite maximal passive oxygen delivery and those who are morbidly obese need positive pressure ventilation for optimal preoxygenation. This is best accomplished with a noninvasive machine or a standard ventilator with pressure support plus PEEP.[13-18] Alternatively, positive airway pressure can be applied using a disposable CPAP mask setup. Using a BVM device with a PEEP valve has been proposed but is not well studied.[19]

HFNO is a simple method for providing both preoxygenation and apneic oxygenation. A before and after study of hypoxemic ICU patients showed that preoxygenation with high-flow nasal cannula (HFNC) was better than using a non-rebreather mask with an O_2 flow rate of 15 L/min,[20] a strategy known to be ineffective. When HFNO is compared to NPPV in ICU patients, two studies have shown that NPPV has slightly lower rates of oxygen desaturation during intubation.[21,22] Studies comparing preoxygenation with HFNO to a high-flow face mask (≥40 L/min), an

anesthesia machine, or a BVM device are needed. Currently, there is not enough information in ED populations to formally recommend HFNO as a preoxygenation strategy, though it seems likely to perform very similarly to a non-rebreather mask at >40 L/min.

Does apneic oxygenation prolong desaturation time during RSI?

In one study of obese patients undergoing general anesthesia, those who received continuous oxygenation using nasal cannula at a 5 L/min flow rate during apnea maintained SpO_2 >95% for significantly longer than controls (5.3 vs 3.5 minutes) and had a significantly higher minimum SpO_2 (94% vs 88%).[23] An observational study of ED RSI showed that apneic oxygenation with a standard nasal cannula was associated with a significant increase in first-pass success without hypoxemia.[24] In addition, a before and after study in the emergency medical services setting showed that the introduction of apneic oxygenation was associated with decreased incidence of desaturation in patients undergoing RSI.[25] Although recent prospective randomized trials showed no benefit of apneic oxygenation after optimal preoxygenation, these results may not generalize to subgroups of higher risk patients or those with unanticipated prolonged laryngoscopy.[26,27] Because there is little downside to providing apneic oxygenation, we recommend that oxygen be routinely delivered via nasal cannula at 15 L/min during the apneic period of RSI.

Can a checklist help improve preoxygenation and avoid hypoxemia during emergency RSI?

Yes, the use of a preprocedural checklist prior to intubation of severely injured trauma patients has been shown to be associated with a significant reduction in oxygen desaturation (<90%) because of increased utilization of maximal preoxygenation and apneic oxygenation.[28]

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CHAPTER 9

Non-Invasive Positive Pressure Ventilation and High-Flow Nasal Oxygen

Alan C. Heffner

INTRODUCTION

Acute respiratory distress is a common emergency, and a thorough knowledge of respiratory support options, both invasive and noninvasive, is essential for practice in acute care medicine. This chapter discusses noninvasive respiratory support strategies (NIRS), whereas Chapter 10 focuses on mechanical ventilation after tracheal intubation. NIRS is now often a first-line support for stabilization of many conditions inciting acute respiratory failure thanks to new technology and evidence-based application demonstrating improved patient outcomes, including reduced rate intubation and reduced length of hospitalization. NIRS supports oxygenation and ventilation through a noninvasive interface, with the added benefits of enhanced patient comfort and preservation of patient interaction, including speech, swallowing, and airway defense mechanisms. Compared to invasive mechanical ventilatory support requiring endotracheal intubation, patients require little to no sedation and benefit from reduced risk of airway injury and nosocomial pneumonia.

TECHNOLOGY OF NONINVASIVE RESPIRATORY SUPPORT

NIRS is provided through either noninvasive positive pressure ventilation (NPPV) or high-flow nasal oxygen (HFNO). Most standard ventilators

provide a NPPV mode, but many centers deploy dedicated NPPV devices with characteristics that are distinct from standard invasive mechanical ventilators. Specialized noninvasive ventilators are smaller portable pressure ventilators with reduced air compressor size. Most have a single-limb circuit that delivers oxygen to the patient and allows for exhalation. To prevent accumulation of carbon dioxide, the circuit is continuously flushed with supplemental oxygen during the expiratory phase with exhaled gas released through an exhalation port near the mask. In contrast to traditional ventilators, NPPV devices continuously monitor for air leak and attempt to compensate for this loss of volume. As such, NPPV units are designed to tolerate some degree of air leak and compensate by maintaining airway pressure.

HFNO requires a dedicated high-flow nasal cannula system that facilitates very high flows of heated and humidified air. An in-line blender allows a titratable F_{IO_2}, and the entire system provides certain airflow characteristics, depending on the brand, that facilitates physiologic benefits similar to NPPV.

The device that makes physical contact between the patient and the ventilator is termed the interface. NPPV interfaces come in a variety of shapes and sizes designed to cover the individual nares, the nose only, the nose and mouth, the entire face, or fitted as a helmet. Interfaces should be selected for patient comfort and to maintain a good seal with minimal leak and limited dead space. HFNO interfaces depend on the brand, with some (eg, Fisher & Paykel Optiflow) cannulas designed to occlude the nares and others (eg, Vapotherm) designed to provide high velocity flow.

MODES OF NONINVASIVE MECHANICAL VENTILATION

Although any ventilator mode may be used for NPPV with characteristics dependent on the mode selection (see Chapter 10), NPPV is most often used in one of two arrangements:

Continuous Positive Airway Pressure

Continuous positive airway pressure (CPAP) mode applies a constant set airway pressure throughout the respiratory cycle. This is equivalent to

extrinsic positive end-expiratory pressure (PEEP) and provides a number of physiologic functions, including increased mean airway pressure, alveolar recruitment to reduce shunt fraction, attenuation of dynamic airway collapse, and reduced threshold to initiate airflow in patients with obstructive lung physiology.

Biphasic Positive Airway Pressure (BiPAP)

Bilevel or biphasic positive airway pressure (BL-PAP or BiPAP) is CPAP with the addition of inspiratory pressure support (PS). The pressure during the inspiratory phase is termed inspiratory positive airway pressure (IPAP). IPAP is always set higher than the expiratory positive airway pressure (EPAP), typically by a minimum of 5 cm H_2O, and the difference between the two settings is equivalent to the amount of PS provided with each breath. The theoretic advantage of inspiratory support above PEEP is improved tidal volume with reduced work of breathing.

Spontaneous and Spontaneous/Timed Modes

In spontaneous mode, the airway pressure cycles between an IPAP and an EPAP. The patient's inspiratory effort triggers the switch from EPAP to IPAP. The limit during inspiration is the set level of IPAP. The inspiratory phase cycles off, and the machine switches to EPAP when it detects cessation of patient effort signaled by a decrease in inspiratory flow rate, or once a set maximum inspiratory time is reached, such as 3 seconds. Tidal volume varies breath to breath and is determined by IPAP, patient effort, and lung compliance. Patient work of breathing is dictated primarily by initiation and maintenance of inspiratory airflow. Spontaneous mode relies on patient effort to trigger each breath. As such, a patient breathing at a low rate can develop respiratory acidosis. The spontaneous/timed (ST) mode prevents this clinical consequence. The trigger in the ST mode can be the patient's effort or an elapsed time interval that is predetermined by a set respiratory backup rate. If the patient does not initiate a breath in the prescribed interval, then IPAP is triggered. For machine-generated breaths, the ventilator cycles back to EPAP based on a set inspiratory time. For patient-initiated breaths, the ventilator cycles as it would in the spontaneous mode.

High-Flow Nasal Oxygen

HFNO systems have adjustable flows, FIO_2, and temperature. All HFNO systems allow for heated and humidified air for comfort and to prevent drying of the mucous membranes. The higher the flow rates (40-60 L/min), the more end-expiratory lung volume is created, which provides a PEEP-like effect that one would get with PEEP/EPAP on NPPV. The combination of flow and FIO_2 supports oxygenation, while the flow itself clears dead space and reduces work of breathing needed for strict ventilatory problems.

INDICATIONS AND CONTRAINDICATIONS

The keys to successfully using NIRS on an emergency basis are patient selection and aggressive therapy to reverse the disease inciting respiratory failure. Eligible patients should be conscious and cooperative, with preserved respiratory drive and ability to manage secretions. Prime targets for NPPV have a disease process that is likely to improve quickly in response to medical management such as acute exacerbation of chronic obstructive pulmonary disease (COPD), moderate to severe asthma, and acute pulmonary edema. NPPV use has been extended to a number of other respiratory situations as a trial of therapy or stabilization in preparation for intubation. HFNO has been shown to be noninferior to NPPV in patients with COPD exacerbations and has shown effectiveness in patients with acute hypoxemic respiratory failure.

NIRS is contraindicated in patients with an immediate threat to the airway, inability to cooperate, mismanagement of oral secretions, or limited spontaneous respiratory drive. Patients should be aware and unrestrained with the capacity to remove the mask interface for secretions or vomiting. For patients in extremis with severe hypoxemia and compromised ventilatory effort, immediate bag mask support followed by intubation is generally preferred over a trial of NPPV, but we highlight the need for clinical judgment in these situations. Increasingly, NPPV and HFNO are used for preoxygenation in preparation for anticipated intubation. HFNO can also be used to support respiratory function during an oral awake intubation.

INITIATING NONINVASIVE RESPIRATORY SUPPORT

For CPAP or BiPAP initiation, a nasal or oronasal mask is required. Varying mask sizes and styles are available, and a respiratory therapist should measure the patient to ensure a good fit and seal. The mask and treatment process should be explained to the patient before applying the mask. Acceptance by the patient may improve by allowing them to hold the mask against their face, prior to placement of securement straps.

Common initiation settings start with 3- to 5-cm H_2O of CPAP with supplemental oxygen dictated by the patient's oximetry and anticipated clinical need. Explain the anticipated pressure changes to the patient as you sequentially increase CPAP by 2- to 3-cm H_2O increments every 5 to 10 minutes, or initiate IPAP to support the patient's respiratory effort. For BiPAP, IPAP is generally set higher than EPAP by at least 5-cm H_2O. Recommended initial settings for BiPAP are IPAP of 8-cm H_2O and EPAP of 3-cm H_2O, providing PS (IPAP minus EPAP) of 5-cm H_2O. EPAP and IPAP are titrated to optimize respiratory assistance in 3- to 5-cm H_2O steps, allowing a brief trial period at each level. Similarly, tidal volume augmentation is best achieved by serial increases of IPAP in 3- to 5-cm H_2O increments, keeping EPAP at the target level. EPAP should generally not exceed 20-cm H_2O.

The same incremental approach applies to the initiation of HFNO. Fit the specialized nasal cannula and introduce the sensation of high nasal flow rates. Initiate flow at 20 L/min and quickly titrate up to flows of 30 to 60 L/min as required to achieve the desired physiologic effect and patient tolerance.

Response to Therapy

The immediate objective of NIRS is to improve pulmonary gas exchange and alleviate respiratory distress and work of breathing. Patients on NIRS must be monitored closely, using familiar parameters such as clinical observation of respiratory work, vital signs, oximetry, and capnography coupled with arterial blood gases (ABGs) as needed. Tolerance of and improvement with NPPV and HFNO is generally recognizable within the first hour of application. Aggressive medical management should be

continued during NIRS. Adjunctive treatments, including inhaled bronchodilators and helium-oxygen mixtures, can be used with NPPV and HFNO. Up to half of patients trialed on NIRS fail and require endotracheal intubation. Persistent tachypnea >30 breaths per minute, declining neurologic status, age, and pneumonia as the cause of respiratory failure are well-recognized factors associated with failing NIRS. Weaning NPPV and HFNO support is performed in a similar stepwise approach to initiation and titration of the therapy. Clinical improvement and stabilization should prompt a trial of therapy weaning and even discontinuation to lower levels of respiratory support as tolerated.

TIPS AND PEARLS

- NIRS patient selection must consider the overall condition of the patient, tolerance of the interface, and the anticipated reversibility of the underlying insult.
- Patients with encephalopathy and inadequate airway protection are poor candidates for NIRS owing to risk of aspiration.
- Patients with both a patent airway and preserved respiratory drive, even if that drive is failing, may be candidates for a trial of NIRS.
- Patients most likely to respond to NPPV and avoid intubation are those with acutely reversible etiologies of respiratory failure, such as COPD exacerbation and acute cardiogenic pulmonary edema.
- NPPV should be accompanied by aggressive medical therapy of the underlying condition (eg, vasodilators and diuretics for pulmonary edema, β-adrenergic agonist, and anticholinergic aerosols and corticosteroids for reactive airways disease).
- Virtually every modern ventilator is capable of delivering NPPV (BiPAP, CPAP) and should be readily accessible in the ED or other critical care areas of the hospital.
- Be prepared for prompt intubation (ie, difficult airway assessment completed along with drugs, equipment, and plan established) in case NIRS fails.

- NIRS response is typically recognized within 30 to 60 minutes of initiation. Early intubation should be considered for patients who fail to improve quickly to avoid complicated emergency intubation in the midst of deterioration on NIRS.

EVIDENCE

When is NPPV most helpful in managing ED patients?

Most studies compare NPPV to standard medical care with favorable outcome measures of endotracheal intubation and ICU and hospital length of stay. Mortality benefit has not been substantiated. In some series, ED patients were successfully supported with NPPV and avoided ICU admission, thereby saving significant health care cost. The strongest level of evidence supports NPPV use for COPD exacerbations and acute cardiogenic pulmonary edema. Uncontrolled studies suggest that NPPV may be successful in a larger variety of patients.[1,2]

What is the role of HFNO?

Studies to date confirm that HFNO is feasible and provides a safe alternative for effective and titratable oxygen therapy in acute hypoxemic respiratory failure.[3,4] Patient tolerance is a recognized benefit compared to traditional oxygen devices, including NPPV, with cumulative data supporting reduced intubation but an unclear impact on mortality. HFNO is a natural adjunct to optimize preoxygenation in patients undergoing emergency intubation and is an attractive option to reduce desaturation in patients suffering acute hypoxemic respiratory failure.[5,6]

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CHAPTER 10

Mechanical Ventilation

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INTRODUCTION

Initiation and management of mechanical ventilation is an important skill for any provider that manages airways. This chapter focuses on initiation of safe and effective invasive mechanical ventilation following endotracheal intubation. Chapter 9 focuses on respiratory failure requiring noninvasive mechanical ventilation.

Spontaneous breathing draws air into the lungs under the negative pressure gradient generated from diaphragm contraction, whereas mechanical ventilation applies positive airway pressure to provide the gradient for airflow. In either case, the amount of negative or positive pressure required to deliver the tidal volume (V_t or TV) must overcome resistance to airflow from both artificial and anatomic airways and distend, or inflate, the lung. Positive-pressure ventilation distinctly alters normal cardiopulmonary physiology compared to spontaneous breathing, with differential effects on the left ventricle (generally improves performance) and right ventricle (generally impairs performance). Importantly, for airway management, transition to positive-pressure ventilation may immediately impede venous return to the heart and alter pulmonary ventilation-perfusion matching.

TERMINOLOGY OF MECHANICAL VENTILATION

The following variables are important for understanding mechanical ventilation:

- **V_t or TV** is the volume of a single breath or respiratory cycle. During mechanical ventilation, the contemporary standard goal TV is ≤8

mL/kg of ideal body weight (IBW). It is important to note that IBW is more a function of patient height than weight or overall size. TVs may be reduced (to 6 or lower mL/kg IBW) in diseases causing unilateral or bilateral lung consolidation (eg, pneumonia and acute respiratory distress syndrome as the most common examples), to minimize ventilator-induced lung injury (VILI) associated with excessive airway pressures that risks overdistention of a reduced fraction of functional lung units.

- The airway conduits do not exchange gas and therefore represent anatomic dead space that accounts for a fixed volume of each TV. Lung units that are well aerated but poorly perfused (eg, the apices) represent physiologic dead space. The remaining TV participates in gas exchange and constitutes alveolar ventilation (minute ventilation—dead space). As TV is reduced, dead space makes up a proportionally larger portion of each breath. As such, it is important to adjust minute ventilation through increased respiratory rate (RR) to balance the decrease in effective alveolar ventilation during intentional TV reduction.
- **RR or frequency (f)** represents the number of breaths per minute. Usual starting RR is 12 to 18 breaths per minute in adults. Higher rates are typical in neonates, infants, and small children. Given our attention to low-TV ventilation, even in patients without lung injury, minute ventilation is typically first modified by increasing RR rather than TV. In addition to compensating for the fixed proportion of dead space mentioned previously, additional increase in RR may also be used to compensate for metabolic acidosis and states of accelerated carbon dioxide (CO_2) production (eg, fever/hyperthermia, sepsis, and hypermetabolic conditions).

In contrast, an important concept of permissive hypercapnia may be required in patients with severe acute lung disease. Permissive hypercapnia refers to the intentional tolerance of respiratory acidosis, by prioritizing lung protective ventilation over normalization of CO_2. In patients with severe obstructive lung physiology such as acute reactive airways, a subnormal RR (6-10 breaths per minute if required) prioritizes adequate expiratory time for complete TV exhalation to avoid retained or “trapped”

air and the repercussions of dynamic hyperinflation and auto-positive end-expiratory pressure (PEEP), which can have significant cardiopulmonary consequences. In the case of acute respiratory distress syndrome (ARDS), permissive hypercapnia permits low-TV lung protective ventilation, without excessive respiratory cycling or injuriously high airway pressures.

- **Fractional concentration of inspired oxygen (F_{IO_2})** ranges from the concentration of oxygen in room air (0.21% or 21%) to that of pure oxygen (1.0% or 100%). When initiating mechanical ventilation, start with F_{IO_2} of 100% and wean based on continuous pulse oximetry monitoring. During acute critical illness, titrating F_{IO_2} to maintain SpO_2 ≥95% is appropriate for most conditions. The lowest F_{IO_2} required to maintain adequate oxygenation should be targeted.
- **Inspiratory flow rate (IFR)** is the rate of TV delivery. In an adult, IFR is typically set at 40 to 60 L/min. Cases of obstructive lung disease may require that peak IFR increase to 90 L/min in order to shorten the inspiratory time (Ti) and thus increase expiratory time and diminish risk for dynamic hyperinflation. Higher IFRs generate greater peak inspiratory pressures, especially under the circumstances of high airways resistance when IFR is often augmented. In contrast, low IFR may contribute to flow starvation when the patient demands a more rapid TV than the ventilator delivers and is a common cause of patient-ventilator dyssynchrony.
- **PEEP** is a static airway pressure maintained during exhalation and is typically set at a minimum of 5 cm H_2O. PEEP increases alveolar recruitment, functional residual capacity, total lung volume, and pulmonary and intrathoracic pressure. When a patient is unable to meet oxygenation goals on F_{IO_2} > 50%, PEEP is typically increased to augment mean airway pressure to improve oxygenation. However, excessive PEEP can lead to pathologic overdistention of healthy lung units, contributing to ineffective gas exchange, barotrauma, and VILI. Elevated intrathoracic pressure can also compromise venous return, with consequent hemodynamic deterioration.
- **Peak inspiratory pressure (P_{IP}) and plateau pressure (Pplat)**: The P_{IP} is the maximum airway pressure reached during the inspiratory

cycle and is a function of resistance in the airway circuit (eg, ventilator circuitry, ETT) and anatomic airways, ventilator IFR, and patient lung and extrapulmonary compliance. P_{IP} is useful for rapid assessment to identify excessive airway pressure that *may* represent an important change in patient condition or equipment problem. Elevated airway pressures do not always reflect elevated alveolar pressure and should not be interpreted as a specific marker of alveolar overdistention that risks barotrauma and VILI. Alveolar pressure and assessment of lung compliance is better represented by P_{plat}, measured at the end of inspiration via a ventilator end-inspiratory hold maneuver. The end-inspiratory pause enables equilibration of pressure between the ventilator and lung units to measure the *static thoracic pressure*, reflecting both alveolar pressure and extrapulmonary compliance. P_{plat} correlates with the risk of VILI, and current recommendations aim to target $P_{plat} \leq 30$ cm H_2O via TV reduction in the context of severe parenchymal lung disease.

VENTILATION MODES

Common contemporary invasive mechanical ventilation modes are best understood by recognizing the differences of three variables: the trigger, the limit, and the cycle.

- The trigger is the event that initiates inspiration: either patient effort or machine-initiated positive pressure.
- The limit refers to the airflow parameter that is used to regulate inspiration: either airflow rate or airway pressure.
- The cycle terminating inspiration: A set inspiratory time is selected in assist control (AC) modes, whereas decreasing inspiratory flow based on patient effort terminates the inspiratory cycle in pressure support ventilation (PSV) mode.

Commonly used ventilation modes are as follows:

- **Assist control (AC)** is the preferred initial mode for patients with acute respiratory failure. AC mode can be either volume targeted via delivery of a set TV in volume-control ventilation (VCV) or pressure

regulated via delivery of a TV guided by set distending pressure administered over a set period in pressure-control ventilation (PCV). In AC mode, the ventilator delivers each breath based on the trigger and terminates the inspiration on reaching the volume or pressure target. The clinician selects the RR, IFR, PEEP, F_{IO_2}, and either the TV or driving pressure in volume and pressure-control settings, respectively.

Importantly, the trigger that initiates inspiration is either patient effort or an elapsed time interval based on the RR. When either of these occur, the ventilator delivers the target volume or pressure. The ventilator synchronizes the set RR with patient efforts, and if the patient is breathing at or above the set rate, then all breaths are patient initiated. Work of breathing (WOB) in AC mode is limited primarily to the patient's effort to trigger the ventilator and can be altered by adjusting the trigger threshold.

- **Synchronized intermittent mandatory ventilation (SIMV with or without PS)** is like AC in most aspects. SIMV can be either volume or pressure targeted, and the clinician selects the RR, IFR, PEEP, F_{IO_2}, and either the volume or pressure target. One important difference between SIMV and AC modes can lead to excessive patient WOB. The trigger that initiates inspiration depends on the patient's RR relative to the set RR. When the patient is breathing at or below the set RR, the trigger can be patient effort or elapsed time. In these cases, the ventilator operates like AC mode. If the patient is breathing above the set RR, the ventilator does not automatically assist the patient efforts, and the TV is determined by effort and resistance to airflow through the endotracheal tube (ETT) and ventilator circuit. In these instances, WOB can be excessive.

  Addition of PSV to the SIMV mode provides a set inspiratory pressure that is applied during patient-initiated breaths, which exceed the set RR. Appropriate PSV balances the inherent resistance of the artificial airways and supports the patient's physiologic situation to limit undue WOB. Insufficient PSV is associated with high RR and low TV, also known as rapid, shallow breathing. Sustained tachypnea greater than 24 breaths per minute is a helpful marker to consider

evaluating if the PSV level is appropriate to the patient condition. SIMV provides no clear benefit over AC mode ventilation. Although previously used as a weaning mode wherein the set rate is progressively decreased to allow the patient to assume increased work, the absence of appropriate PSV substantially increases WOB and is frequently overtaxing. Spontaneous breathing trials using PSV, without SIMV, is the current standard approach to assess readiness for liberation from mechanical ventilation.

Pressure Support Ventilation

Pressure support delivers a set inspiratory pressure during each patient-initiated breath like noninvasive positive-pressure ventilation (ie, BiPAP). In PSV mode, the patient determines the RR, initiation, and termination of each breath. The delivered TV is dependent on patient effort and the degree of PS applied. This mode is often used during ventilator weaning and should generally not be used as the initial mode following emergency intubation or patients at risk for hypoventilation or apnea, because there is no mandatory or minimum backup rate to support the patient.

VENTILATOR TV DELIVERY

Volume-Control Ventilation

In this method of delivering a breath, the operator selects the TV of each breath. Initial TV is typically set at ≤8 mL/kg IBW. The pressure applied to deliver this volume varies by the flow rate selected, the resistance of the airway circuit and lungs, and compliance of lungs and thorax. The dependent variables of air pressure (P_{IP} and P_{plat}) are monitored to confirm safe and appropriate ventilation (**Fig. 10.1**).

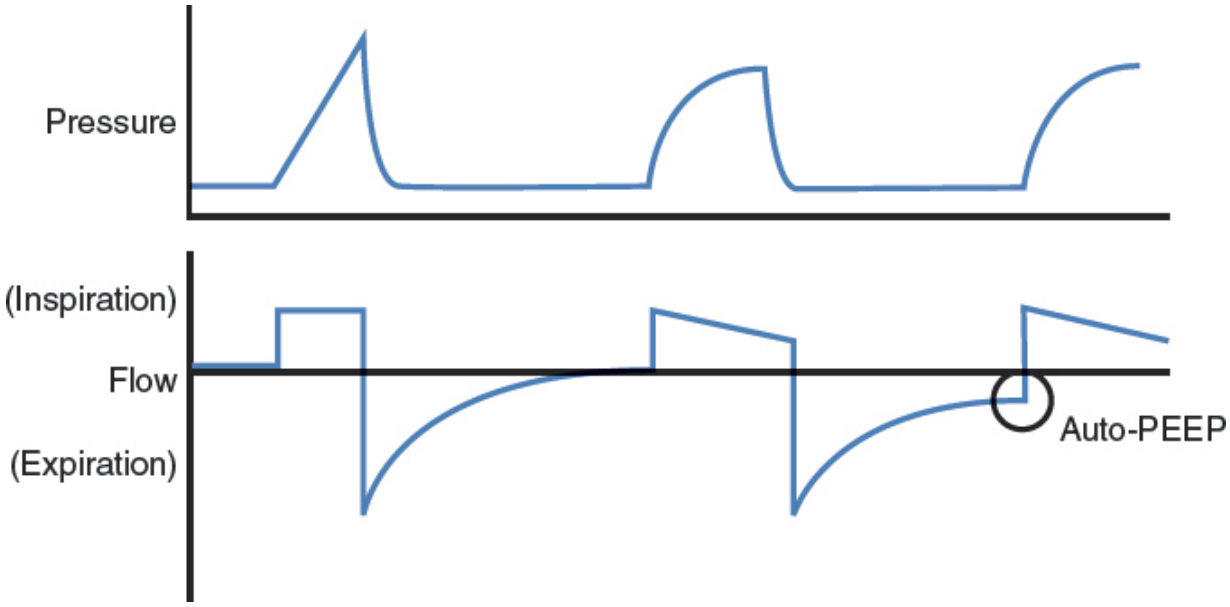

Figure 10.1: Volume-control ventilation (VCV). The lower trace demonstrates a square flow waveform first, followed by a decelerating waveform. Note that the peak pressure generated by the square waveform exceeds that of the decelerating waveform. The third waveform demonstrates breath initiation before expiratory flow reaches zero. This is an example of breath stacking that leads to dynamic hyperinflation and auto-positive end-expiratory pressure (PEEP).

Pressure-Control Ventilation

In converse, PCV delivers a set airway distending pressure over a selected inspiratory time (T_i), with TV monitored as the dependent variable. Breath to breath variation in TV is expected owing to airway resistance, lung compliance, and patient effort, but the PCV setting should be adjusted to meet the standard ≤8 mL/kg IBW goal.

With pressure targeted modes, the peak flow of the administered tidal breath and the flow waveform vary according to airway and lung characteristics. Early in inspiration, the ventilator generates a flow rate that is sufficiently rapid to reach the preset pressure and then automatically alters the flow rate to stay at that pressure and cycles off at the end of the predetermined Ti. The flow waveform created by this method is a decelerating pattern (**Fig. 10.2**). A normal inspiratory to expiratory (I:E) ratio is 1:2. If the RR is 10 breaths per minute evenly distributed over a minute, each cycle of inspiration and expiration is 6 seconds. With an I:E ratio of 1:2, inspiration is 2 seconds, and expiration is 4 seconds.

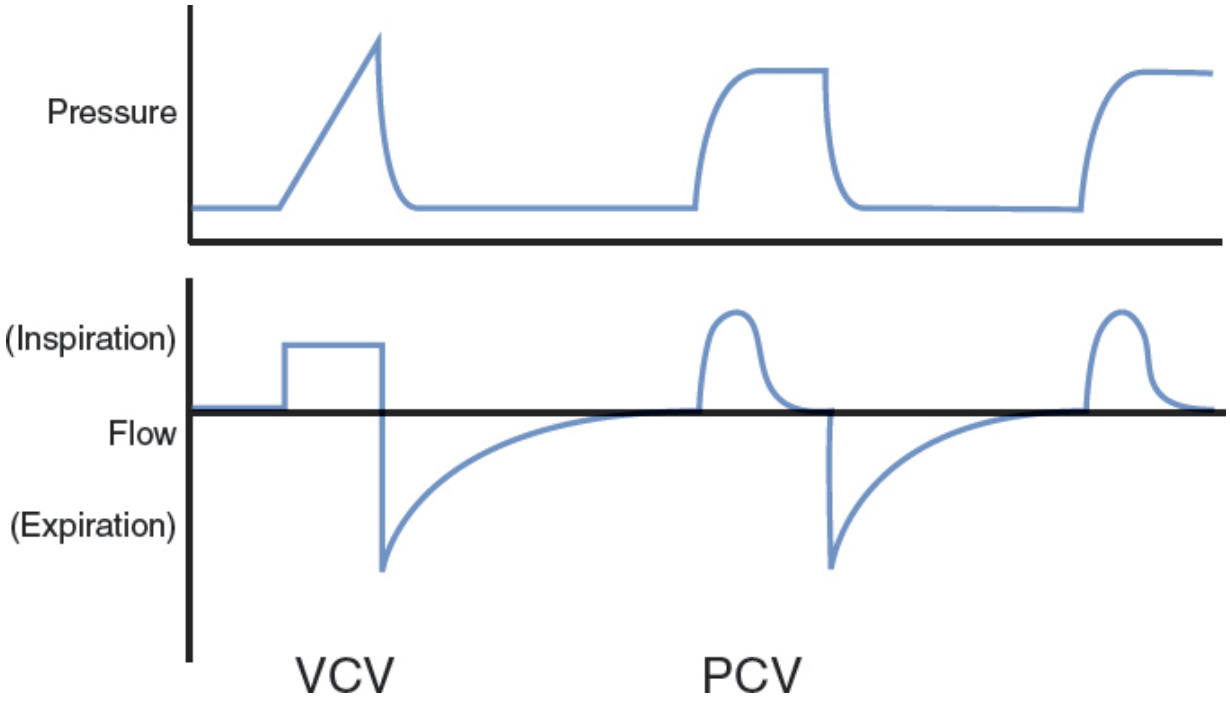

Figure 10.2: Pressure-control ventilation (PCV). These waveforms demonstrate the differing waveform characteristics between volume-control Ventilation (VCV) and PCV. Note that PCV generates lower peak pressures than VCV.

The I:E ratio describes the relative durations of each portion of the respiratory cycle. Normal I:E is 1:2, and this is a typical starting point for ventilator settings. The most common need for early adjustment of I:E is in situations of severe obstructive lung disease. The pressure and flow waveforms on the ventilator monitor allow recognition of end-expiratory flow. Terminal end-expiratory flow should approach zero to confirm exhalation is complete and thereby avoid retained intrathoracic volume of the preceding TV. Small fractions of retained TV compounded by the ventilator rate lead to dynamic hyperinflation, with consequences of increased intrathoracic pressure, known as auto-PEEP, that affect venous return and respiratory mechanics and risk barotrauma (**Fig. 10.3**). In contrast, overly brief Ti can lead to low TVs and hypoventilation.

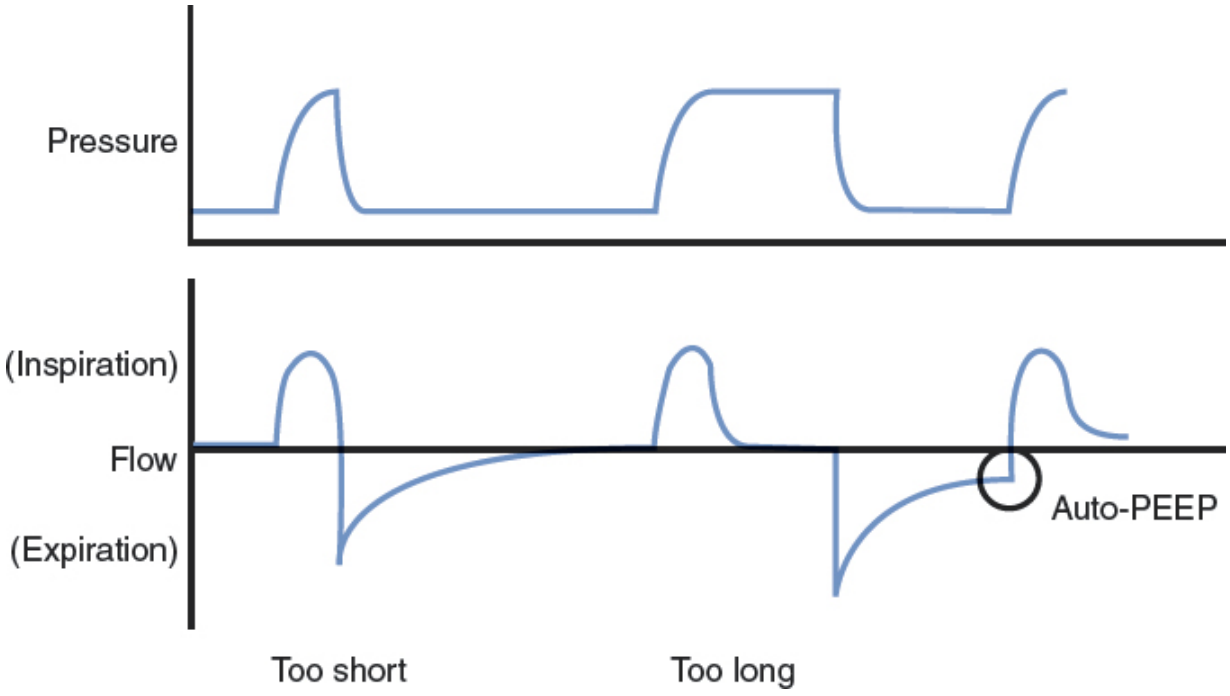

Figure 10.3: Pressure-control ventilation and inspiratory-expiratory (I:E) ratio.

INITIATING MECHANICAL VENTILATION

The patient who is spontaneously breathing possesses a complex series of physiologic feedback loops that control the volume of gas moved into and out of the lungs each minute (minute ventilation). They automatically determine the RR and the volume of each breath necessary to effect gas exchange and maintain homeostasis. Ventilator-dependent patients have no such servo control and must rely on individualized ventilator settings to meet their physiologic needs. In the past, this required frequent blood gas determinations. Now, we rely more heavily on noninvasive techniques such as pulse oximetry with or without end-tidal CO_2 ($ETCO_2$) monitoring.

The ventilation required to remove the CO_2 produced by metabolism and delivered to the lungs by the circulatory system is commonly measured as minute ventilation or minute volume. Minute volume approximates 100 mL/kg, under normal metabolism. Hypermetabolic and febrile patients can produce up to 25% more CO_2 compared with normal resting state, and minute ventilation must be increased proportionally to accommodate this increased production.

Our recommended initial ventilator settings for adult patients are shown in **Box 10.1**. For most patients, this formula produces reasonable gas exchange to provide adequate oxygenation and ventilation. The components of minute ventilation (TV and RR) can be manipulated to provide more detailed minute volume based on blood gas analysis. If smaller TV is needed, compensatory increase in RR may be required. Although most mechanical ventilation can be titrated by noninvasive measures using oxygen saturation by pulse oximetry and $ETCO_2$, we endorse an initial blood gas to assess the appropriateness of initial ventilator settings and accuracy of $ETCO_2$ monitoring.

BOX 10.1 Recommended Initial Ventilator Settings for Adult Patients. ***See text for abbreviations.***

- Mode: Assist-control (AC) mode to volume-control (VC) setting
- TV: 7 mL/kg IBW
- Rate: 10 to 14 breaths per minute
- F_{IO_2}: 1.0
- PEEP: 5.0 cm H_2O
- IFR: 60 L/min

Alveolar overdistention and high airway pressure risks VILI during mechanical ventilation, and thus the recommended starting TV ≤ 8 mL/kg IBW. For patients with lung consolidation (eg, pneumonia, ARDS), the most difficult task in optimizing mechanical ventilation is balancing TV and distending lung volume and pressure. Plateau airway pressure correlates with the risk of VILI, and current recommendations aim to maintain $P_{plat} \leq$ 30 cm H_2O. Because many of these patients require PEEP augmentation for oxygenation, optimization mandates TV reduction approximating 5 to 7 mL/kg IBW.

Positive-pressure ventilation increases intrathoracic pressure that can limit cardiac venous return or worsen right ventricular performance. This can compromise cardiovascular performance and precipitate shock or even

cardiac arrest (ie, pulseless electrical activity). High PEEP and/or auto-PEEP pose a greater risk of cardiovascular impact. These effects are more pronounced in the context of hypovolemia or right ventricular dysfunction.

In other situations, ventilator modifications aim to balance minute ventilation with airflow dynamics. The intubated patient with obstructive lung disease such as status asthmaticus is a common example. Minute ventilation aims to provide reasonable ventilation relative to CO_2 production but must be balanced with the priority of complete TV exhalation to avoid dynamic hyperinflation. *Respiratory frequency has the greatest impact on expiratory time* and should start as low as 6 or 8 breaths per minute in patients with severe obstructive lung disease. The inspiratory cycle can also be shortened by increasing the IFR to lengthen I:E, but the impact of IFR is small compared with RR. Auscultation of the chest is a rapid means to clarify whether initiation of the next ventilator TV occurs before complete exhalation (typically manifest as persistent wheezing). Incomplete exhalation, commonly called "breath stacking," leads to dynamic hyperinflation. The flow-time graphic on modern ventilators is helpful as return to zero flow with each respiratory cycle helps confirm adequate exhalation period. Even this, however, is an incomplete picture because the pressures and flow are measured at the airway opening. Small airways with complete obstruction on exhalation will go unseen on ventilator waveforms.

In extreme cases, deliberate hypoventilation is performed to avoid dynamic hyperinflation and high intrathoracic pressure that can lead to cardiovascular compromise from limited venous return. This permissive hypercapnia (respiratory acidosis with pH > 7.20) is the expected cost of a low minute ventilation strategy. Equipment considerations may also contribute to airflow obstruction and deserve special attention (**Box 10.2**).

BOX 10.2 Recommendations for Mechanical Ventilation for Adult Patients With Obstructive Lung Physiology. *See text for abbreviations.*

- Set initial RR at 8 breaths per minute.
- Set initial TV at 7 mL/kg IBW.
- Use clinical auscultation and ventilator flow-time graphics to confirm cessation of airflow prior to the following breath initiation.

TIPS AND PEARLS

- Review the features and graphics of ventilators available at your institution with a respiratory therapist (RT). Make sure that your RTs are familiar with the ARDSnet protocol, P_{plat} measurements, and the concept of permissive hypercapnia.
- When a patient deteriorates, you must know how to take a patient off the ventilator and resume manual bag ventilation if needed. Learn how to place the ventilator on standby mode and silence the alarms. These steps will preserve calm until an RT or other help can respond. Manual bag ventilation deals effectively with temporary ventilator malfunction and provides immediate feedback of airway, pulmonary, and thoracic resistance and compliance. When using manual bag ventilation, be sure to use a PEEP valve, and be cognizant of the large tidal volumes delivered by the bag (often 1 L or more).
- Understand the typical resistance and compliance characteristics of various respiratory disorders. This information can help predict specific TV and RR settings and measures for your initial ventilator settings.
- Use AC as your primary ventilator mode following intubation. This mode provides full support for patients at risk of hypoventilation and avoids unnecessary WOB for those triggering the ventilator. VCV is more intuitive for many providers and is our recommended initial mode.

EVIDENCE

Explain the concept of permissive hypercapnia in acute bronchospasm.

All patients are capable of trapping inspired air if the expiratory period is inadequate. Patients with obstructive lung physiology are particularly vulnerable given the prolonged period required for complete TV exhalation. Maximizing expiratory period through ventilator modifications (ie, low RR, normal TV, rapid IFR) may require sacrificing minute ventilation in order to avoid dynamic hyperinflation. Permissive hypercapnia is the technique of

intentional hypoventilation with tolerance of respiratory acidosis until the bronchospasm responds to treatment. Moderate to severe acidemia (pH > 7.20) is well tolerated. Neuromuscular blockade is often required to suppress patient respiratory effort from triggering the ventilator in this situation. Supranormal P_{IP} is common even with appropriate settings owing to high airway resistance, but this pressure is dissipated in the airways. Confirmation of normal P_{plat} demonstrates safe alveolar distending pressure.

What is the current ventilator-induced lung injury (VILI) in acute respiratory distress syndrome (ARDS)?

Contemporary mechanical ventilation aims to minimize VILI induced by lung overdistention, even in patients without pulmonary disease. High inspiratory airway pressures are associated with adverse outcome, and low TV (≤8 mL/kg IBW) reduces mortality and ventilator days in patients with ARDS.[1] Recognizing that TV is distributed predominantly to healthy, patent alveoli, lower TV prevents overdistention injury of functional lung units. P_{plat} (goal ≤ 30 cm H_2O) is used as the surrogate measure of lung compliance to individualize the appropriate reduction of TV. Further reduction in TV (5-6 mL/kg IBW) may be required to minimize distending pressure to meet this goal in patients with severe lung disease.

Early neuromuscular blockade generally improves gas exchange in patients with severe lung disease, presumably via removal of metabolic demands of respiratory effort and patient-ventilator dyssynchrony. Early continuous paralysis may improve mortality in patients with severe ARDS (defined by partial pressure of arterial oxygen $[PaO_2]/FIO_2$ < 150).[2] Attention to maintain appropriate sedation under the influence of neuromuscular blockade is essential to avoid patient awareness.

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CHAPTER 11

Oxygen and Carbon Dioxide Monitoring

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PULSE OXIMETRY

The amount of oxygen reversibly bound to hemoglobin in arterial blood, defined as hemoglobin saturation ($Sa{O_2}$), is a critical element of systemic oxygen delivery. Clinical detection of hypoxemia by physical examination alone is unreliable. Pulse oximetry ($Sp{O_2}$) enables real-time, noninvasive, continuous measurement of arterial oxygen saturation at the bedside. Reliable interpretation of the information provided by these devices requires appreciation of their technology and limitations.

Principles of Measurement

Pulse oximetry relies on the principle of spectral analysis, which is the method of analyzing physicochemical properties of matter based on their unique light absorption characteristics. For blood, absorbance of transmitted light is dependent on the concentration of hemoglobin species. Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through than deoxygenated hemoglobin.

Oximeters consist of a light source, photodetector, and microprocessor. Light-emitting diodes (LEDs) emit high-frequency signals at 660 nm (red) and 940 nm (infrared) wavelengths. When positioned to traverse or reflect light from a cutaneous vascular bed, the opposed photodetector measures the light intensity of each transmitted signal. Signal processing exploits the pulsatile nature of arterial blood to isolate arterial saturation. The

microprocessor averages these data over several pulse cycles and compares the measured absorption to a reference standard curve to determine hemoglobin saturation, which is displayed as a percentage of oxyhemoglobin (Spo_2). Spo_2 and Sao_2 correlation vary with manufacturer; they exhibit high accuracy (±2%) within normal physiologic range and circumstances but with disparities among race, with darker skin tones having slightly lower Spo_2 values, on average.

Anatomic locations with high vascular density are preferred for probe placement, and two oximetry techniques are used in clinical practice. The first, transmission oximetry, deploys the LED and photodetector on opposite sides of a tissue bed (eg, digit, nose, or ear lobe) such that the signal must traverse tissue. The second, reflectance oximetry, positions the LED and photodetector side by side on a single surface and can be placed in anatomic locations without an interposed vascular bed (eg, forehead). This facilitates more proximal sensor placement with improved response time relative to core body Sao_2.

Indications

Pulse oximetry provides important, real-time physiologic data and is the standard noninvasive measure of arterial hemoglobin saturation, which is widely considered a standard patient vital sign. Continuous monitoring is indicated for any patient at risk or in the midst of acute cardiopulmonary decompensation. Reliable continuous oximetry is mandatory for patients requiring airway management and should be a component in each preintubation checklist. If placed on an extremity, the probe is preferably placed on the opposite side of the blood pressure cuff to avoid interruptions in Spo_2 readings during cuff cycles.

Limitations and Precautions

Pulse oximeters have several important physiologic and technical limitations that influence bedside use and interpretation (**Table 11.1**).

TABLE 11.1 Etiology and Examples of Unreliable Pulse Oximetry

Etiology	Examples

Sensor location	Critical illness (forehead probe is best)
	Extraneous light exposure
Motion artifact	Exercise
	Cardiopulmonary resuscitation (CPR)
	Seizure
	Shivering/tremor
	Prehospital transport
Signal degradation	Hypothermia
	Hypotension/shock
	Hypoperfusion
	Vasoconstriction
	Nail polish/synthetic nails
Physiologic range	Increasingly inaccurate when systolic blood pressure <80 mm Hg
	Increasingly inaccurate when Sao_2 <75%
	Severe anemia
	Sickle cell anemia
Dyshemoglobinemia	Carboxyhemoglobin (CO-Hgb) (overestimates Spo_2)
	Methemoglobin (Met-Hgb) (variable response)
Intravenous dye	Methylene blue
	Indocyanine green

Signal Reliability

Proper pulse oximetry requires pulse detection to distinguish light absorption from arterial blood relative to the background of other tissues. Abnormal peripheral circulation as a consequence of shock, bradycardia, vasoconstriction, or hypothermia may prevent pulsatile flow detection. The monitor display of heart rate and plethysmographic waveform verifies arterial sensing; SpO_2 should be considered inaccurate unless corroborated

by these markers. Varying pulse amplitude is easily recognized on the monitor and represents the measure of arterial pulsatility at the sampled vascular bed. Quantification in the form of perfusion index (the ratio of pulsatile flow to nonpulsatile flow) is being incorporated into some software to verify signal reliability and gauge microvascular flow.

Even with verified signal detection, measurement bias limits Spo_2 reliability during physiologic extremes. Reliability deteriorates with progressive hypotension with systolic blood pressures below 80 mm Hg. In these patients, readings generally underestimate true Sao_2. Severe hypoxemia with Sao_2 <75% is also associated with increased measurement error as comparisons to reference standards are limited below this value. However, patients with this degree of hypoxemia are typically receiving maximized intervention, and closer discrimination in this range rarely imparts new information that alters management.

A number of physical factors affect pulse oximetry accuracy. Signal reliability is influenced by sensor exposure to extraneous light, excessive movement, synthetic fingernails, nail polish, intravenous dyes, severe anemia, and abnormal hemoglobin species. Diligent probe placement and shielding the probe from extraneous light should be routine. Surface extremity warming may improve local perfusion to enable arterial pulse sensing, but Spo_2 accuracy using this technique is not confirmed.

Dyshemoglobinemias such as carboxyhemoglobin (CO-Hgb) and methemoglobin (Met-Hgb) absorb light at different wavelengths and may affect the accuracy of oximetry readings. Co-oximeters (and some new-generation pulse oximeters) use four wavelengths of light stimulus to selectively discriminate these species. However, CO-Hgb absorbance is close to oxyhemoglobin such that most conventional pulse oximeters sum up their measurement and give artifactually high Spo_2 readings. Met-Hgb produces variable error, depending on the true oxy- and Met-Hgb levels. Spo_2 classically approximates 85% in severe toxicity.

Response Time

Pulse oximetry readings lag the patient's physiologic state; signal averaging of 4 to 20 seconds is typical of most monitors. Delay because of sensor

anatomic location and abnormal cardiac performance compound the lag relative to central SaO_2. Forehead and ear probes are closer to the heart and respond more quickly than distal extremity probes. Response difference compared to central SaO_2 is also compounded by hypoxemia (ie, starting on the steep portion of the oxyhemoglobin dissociation curve) and slower peripheral circulation such as low cardiac output states. As such, forehead reflectance probes are often preferred in critically ill patients. All of these response delays become more clinically important during rapid oxygen desaturation that may occur during airway management. This is the basis for our general recommendation to abort most intubation attempts when the SpO_2 falls below 93%.

Physiologic Insight and Limitations

Hemoglobin saturation is just one assessment of systemic oxygenation. Although monitoring is continuous, SpO_2 provides real-time information on arterial hemoglobin saturation without true insight into systemic oxygenation and respiratory reserve. Knowledge of the physiologic context of oximetry is critical for appropriate interpretation and assists estimation of a patient's cardiopulmonary reserve for planning and execution of an airway management plan.

Oximetry measures arterial hemoglobin saturation but not the arterial oxygen tension or oxygen content of blood. The oxyhemoglobin dissociation curve (see Chapter 20) describes the relationship of oxygen partial pressure (PaO_2) and saturation (SaO_2). Its sigmoidal shape hinges on varying hemoglobin affinity with successive oxygen binding. It is important to note that normal SpO_2 values correlate poorly with PaO_2 when the patient is breathing supplemental oxygen. Normal SpO_2 is associated with a wide range of PaO_2 (80-400 mm Hg), which includes two extremes of oxygen reserve. Therefore, oximetry is insensitive at detecting a significant decline in oxygen reserve in patients with high baseline PaO_2. Correlation is established in the hypoxemic range at and below the upper inflection point of the oxyhemoglobin curve (PaO_2 ~ 60 mm Hg approximating SaO_2 90% at normal pH) where desaturation is rapid with declining PaO_2. Although obtaining an arterial blood gas (ABG) prior to emergency intubation is

often technically and logistically difficult and should never be prioritized over other preparatory steps, it can be helpful when developing a strategy for intubation (ie, deciding between proceeding with rapid sequence intubation [RSI] or awake intubation) in patients with hypoxemic respiratory failure. A low Pa_{O_2}, even with an acceptable Sp_{O_2} while preoxygenating with flush rate oxygen and/or positive end-expiratory pressure (PEEP), indicates a very high shunt fraction, and safe apnea time may be minimal to nonexistent after RSI meds are administered (see Chapter 3).

Hemoglobin saturation must also be interpreted in the context of inspired oxygen fraction (F_{IO_2}) to provide insight into gas exchange and physiologic reserve. Simple observation at the bedside provides qualitative assessment. More formal calculation of the Sp_{O_2}/F_{IO_2} (SF) ratio is advocated, clinical circumstances permitting. For the same reasons discussed earlier, SF ratio correlates with Pa_{O_2}/F_{IO_2} (PF) ratio in the hypoxemic range (Sp_{O_2} <90%) but not in the normal range, and gives an estimate of the patient's shunt (how much of the external supplemental oxygen does not interface with blood flow). As such, observation of the patient's condition before supplemental oxygen escalation or preoxygenation provides more insight into the physiologic state. Correct interpretation of Sp_{O_2} relative to F_{IO_2} is also important in assessing for failure of noninvasive ventilation. Preintubation hypoxemia despite maximal oxygen supplementation or a requirement of oxygen escalation above F_{IO_2} >70% to maintain normal oxygen saturation leaves a thin margin of physiologic reserve for preoxygenation and execution of safe, uncomplicated endotracheal intubation.

Although Pa_{O_2} (with or without conscious calculation of PF ratio) is a traditional and reliable gauge of pulmonary gas exchange and reserve, measurement of Pa_{O_2} through ABG sampling before airway management is not generally helpful unless the patient has severe or refractory hypoxemia (see Chapter 3). The aim to maximize preoxygenation in all patients supersedes this strategy. However, knowledge of these principles and relationships provides insight into physiologic events and the fallibility of current technology during the management of critical illness.

The context of cardiac performance is also vital to interpretation of oximetry data. Although saturated hemoglobin accounts for the majority of blood oxygen content, systemic oxygen delivery is largely regulated by, and can be limited by, cardiac performance. Pertinent to airway management, rapid desaturation and delayed response to pulmonary oxygenation should be anticipated in the setting of low cardiac output.

Finally, oxygen saturation is an unreliable gauge of ventilation, arterial CO_2 ($PaCO_2$) level, and acid-base status. Normal arterial saturation does not ensure appropriate ventilation. Oxygenation often is adequate with minimal volume of gas exchange, whereas carbon dioxide (CO_2) removal relies on pulmonary ventilation. ABG analysis is the traditional means to measure $PaCO_2$, but alternative noninvasive CO_2 monitoring provides additional insight.

END-TIDAL O_2 MONITORING

Clinicians can monitor the effectiveness of preoxygenation by measuring end-tidal oxygen (ETO_2), the oxygen concentration at the end of an exhaled breath. ETO_2 is measured in much the same way as end-tidal CO_2 ($ETCO_2$) and requires a separate module that connects to the vital sign monitor. For nonintubated patients, a special nasal cannula with a sampling line can be used to measure ETO_2. For intubated patients or if bag valve mask or noninvasive positive pressure ventilation is used for preoxygenation, there is also the option of placing the sampling line aligned with the bag or machine. Some machines display numeric ETO_2 values only, and others display a continuous waveform.

The maximum achievable ETO_2 is between 85% and 90%, and in ideal circumstances the measured ETO_2 reflects the alveolar oxygen concentration. Therefore, if using ETO_2 to guide preoxygenation, the clinician should attempt to achieve an ETO_2 value of >85%. There have been two small emergency department (ED)-based studies of ETO_2 use in the ED. Notably, comparing time periods when clinicians had access to ETO_2 information to when they did not, patients had higher ETO_2 values before intubation and had less frequent oxygen desaturation during

intubation. This indicates that ETO_2 may be useful to assess the effectiveness of preoxygenation, especially when a bag valve mask is used. Common methods to improve preoxygenation if an ETO_2 value of >85% could not be achieved included: improving the mask seal (if using a bag valve mask device), increasing the duration of preoxygenation, increasing the flow of oxygen (if using a non-rebreather mask), and, less commonly, switching from a non-rebreather mask to a bag valve mask. Notably, only two-thirds of patients achieved an ETO_2 >85% when the clinician had access to the information, despite these preoxygenation changes.

ETO_2 use, however, has important limitations. There are many possible scenarios in which the measured ETO_2 will be >85% while the patient has inadequate preoxygenation. If the patient is apneic or breathing small tidal volumes, the monitor will detect mostly the inflow of oxygen rather than actual alveolar oxygen content. Similarly, if a bag valve mask is used but a large mask leak is present so that the patient is mostly breathing in and out room air, the sidestream port will detect fresh inflow of oxygen rather than actual exhaled breath. An astute clinician will recognize these problems from simple observation of the patient, but these examples serve as a reminder to use technology as an adjunct to clinical judgment rather than to supplant it.

END-TIDAL CO_2 MONITORING

CO_2 is a normal by-product of systemic metabolism. The quantity of expired CO_2 is dependent on three factors: metabolic production, venous return and pulmonary circulation to deliver CO_2 to the lungs, (dead space) and alveolar ventilation. Capnography, therefore, provides insight into these factors. The corollary is that interpretation of exhaled CO_2 is not always straightforward as a consequence of its dependence on these functions.

Basics of CO_2 Monitoring

CO_2 monitors measure the partial pressure of CO_2 (in mm Hg) in expired gas. A variety of methods and devices are available. Qualitative (or semiquantitative) colorimetric monitors simply detect expired CO_2 above a

threshold concentration. Quantitative devices include non-waveform capnometers and waveform capnographers, which display the partial pressure of CO_2 in each breath. When measured at the end of expiration, this is referred to as $ETCO_2$, which can approximate alveolar CO_2. Waveform capnographers display a continuous waveform, representing exhaled CO_2 concentration over time and therein provide the most comprehensive data on ventilation, metabolism, and perfusion.

Colorimetric CO_2 Detectors

Colorimetric CO_2 detectors use pH-sensitive filter paper impregnated with metacresol purple, which changes color from purple (<4 mm Hg CO_2) to tan (4-15 mm Hg CO_2) to yellow (>20 mm Hg CO_2), depending on the concentration of exhaled CO_2. The indicator, housed in a plastic casing, is typically interposed between the ET tube and ventilator bag. Qualitative colorimetric detectors are inexpensive and easy to use, making them an excellent choice for tracheal tube confirmation. One important limitation of qualitative colorimetric detectors is that they have a 25% false-negative rate (ie, no color change with correct intubation) in the setting of (usually prolonged) cardiac arrest resulting from the absence of circulatory distribution of CO_2 to the lungs.

Quantitative CO_2 Monitors

Quantitative monitors include non-waveform capnometers, which display $ETCO_2$ of each breath, and waveform capnographers, which display $ETCO_2$ and a continuous waveform representing exhaled CO_2 over time (**Fig. 11.1**). Most of these devices use an infrared sensor, which measures the amount of infrared light absorbed by CO_2 in the exhaled gases.

Figure 11.1: Waveform capnographer. Display showing the $ETCO_2$ value (<) with each breath and a waveform (<) representing exhaled CO_2 concentration over time.

There are two types of capnographers: sidestream monitors withdraw gas samples from the airway with a thin tube, and mainstream monitors sample gas with an in-line sensor. Both types can be used for intubated patients. Nonintubated patients undergoing sedation are usually monitored with a sidestream capnographer through a nasal cannula. Of note, if a sidestream capnography nasal cannula is used preintubation, it cannot be used for apneic oxygenation. The nasal prongs are the sampling line and the oxygen is delivered through small holes in front of the nose. Using these cannulas for apneic oxygenation would not provide any oxygen into the nasopharynx. Capnography face masks that use both sidestream and mainstream technology are also available for monitoring nonintubated patients.

Capnography Interpretation

In healthy patients, a close correlation exists between $ETCO_2$ and $PaCO_2$ such that $ETCO_2$ is approximately 2 to 5 mm Hg less than $PaCO_2$ (normal $ETCO_2$ is 35-45 mm Hg). Unfortunately, changes in ventilation and perfusion alter the alveolar to arterial gradient such that absolute $PaCO_2$ can be difficult to predict based on capnography. This does not detract from the utility of capnographic waveform and trend analysis (**Table 11.2**).

TABLE 11.2 Abnormal $ETCO_2$ Values		
$ETCO_2$	**Physiology**	**Clinical Condition**
Increased	Decreased CO_2 clearance	Classic hypoventilation
	Increased circulation	Return of spontaneous circulation in cardiac arrest
	Increased CO_2 production	Increased metabolism (fever and seizure)
Decreased	Increased CO_2 clearance	Hyperventilation
	Lack of CO_2 in gas	Hypopneic hypoventilation
	Sample decreased circulation	Low cardiac output
	Decreased CO_2 production	Pulmonary embolism
		Decreased metabolism (hypothermia)
Zero	No ventilation	Esophageal intubation
		Accidental extubation
		Apnea
	No circulation	Cardiac arrest

Capnography monitors can display at a high recording rate, which allows assessment of individual waveforms, or a low recording rate, which allows a better assessment of trends (**Figs. 11.2** and **11.3**). A normal waveform has a characteristic rectangular shape and should start from 0 mm Hg and return to 0 mm Hg. Elevation of the baseline above zero implies CO_2 rebreathing or hypoventilation. The upstroke should be rapid and almost vertical. A slurred upstroke occurs with expiratory obstruction caused by bronchospasm, chronic lung disease, or a kinked tube. The plateau tends to slope gently upward to the end of expiration where the $ETCO_2$ value is measured. Beginning with inspiration, there is a rapid vertical drop back to the baseline.

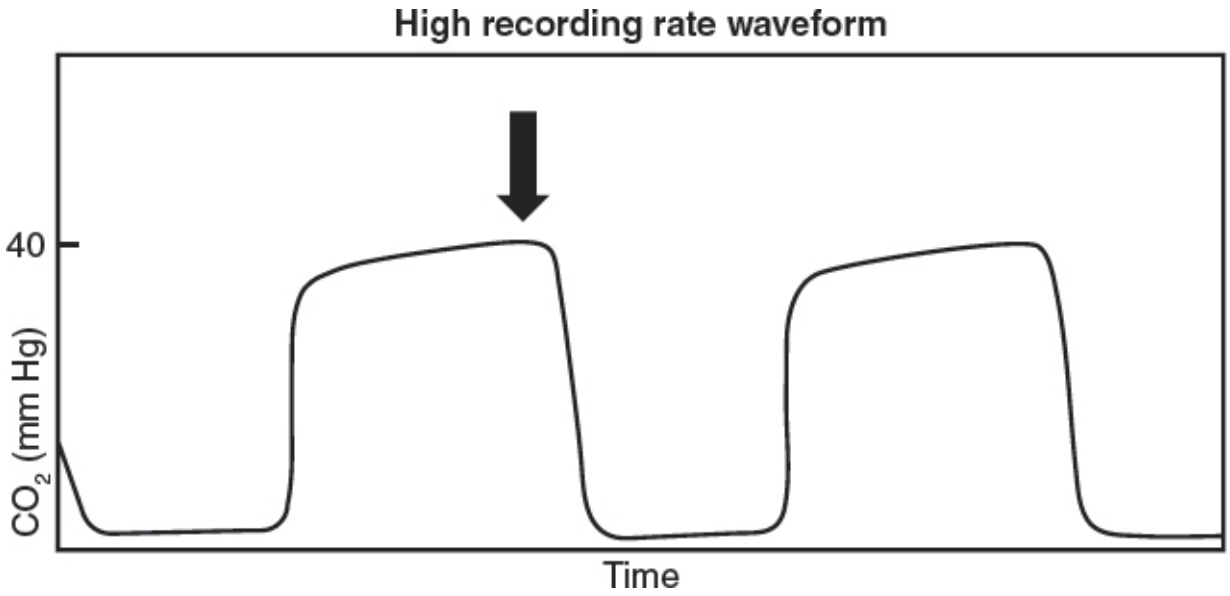

Figure 11.2: Normal capnography waveform at a high recording rate (12.5 mm/sec) with a characteristic rectangular shape. The upstroke and downstroke are nearly vertical, the plateau rises slightly throughout expiration, and the $ETCO_2$ value (about 40 mm Hg) is measured at the end of expiration (arrow).

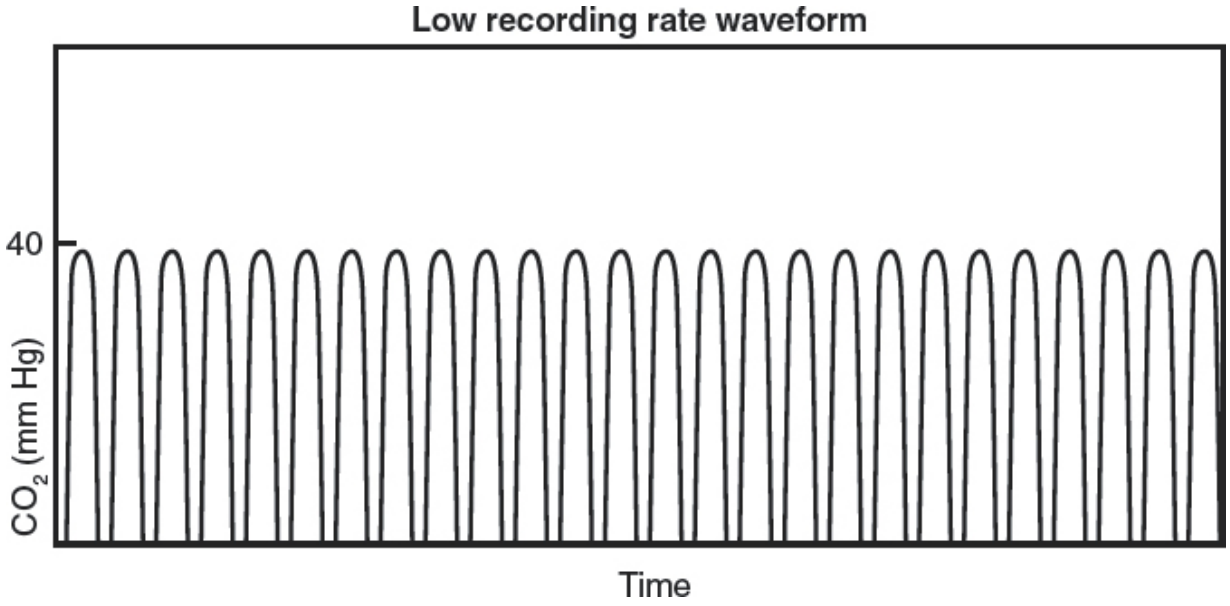

Figure 11.3: Normal capnography waveform at a low recording rate (25 mm/min). The low recording rate is useful for monitoring $ETCO_2$ trends, not waveform shape.

Clinical Utility of Quantitative Capnometry and Capnography

Confirmation of ET Tube Placement and Detection of Accidental Extubation

Continuous waveform capnography and non-waveform capnometry are the most accurate methods for initial and ongoing confirmation of proper ET tube placement. Esophageal intubation results in an absent or abnormal $ETCO_2$ value or waveform after the first few breaths (**Fig. 11.4**). When the waveform is completely absent immediately after an apparently successful intubation, the intubator should consider revisualizing the tube in the airway, especially when videolaryngoscopy is being used, because lack of an $ETCO_2$ waveform can also occur with monitor malfunction. Correct tube placement results in a reasonable $ETCO_2$ value and a characteristic rectangular waveform. The $ETCO_2$ value and waveform can be continuously monitored during prehospital and intrahospital transport. Sudden waveform loss is the earliest sign of accidental extubation and may precede oxygen desaturation by minutes.

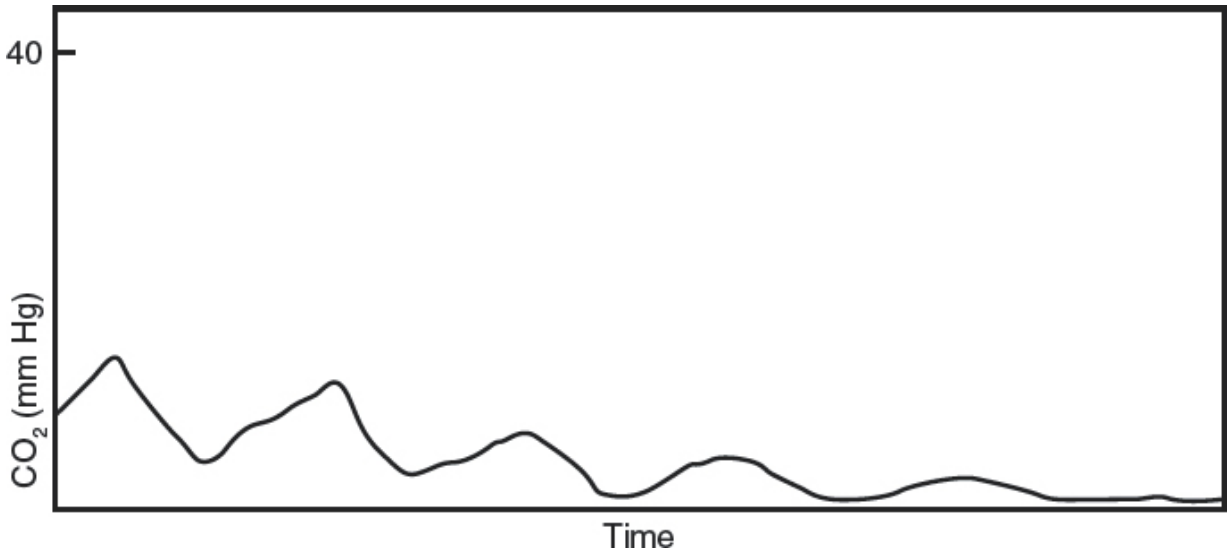

Figure 11.4: Esophageal intubation. Note that there is a minimal abnormal waveform that disappears within five to six breaths.

Capnography During Cardiopulmonary Resuscitation

Capnography is a sensitive indicator of cardiovascular status. Exhaled CO_2 is dependent on pulmonary circulation, which is absent during untreated cardiac arrest. The 2015 American Heart Association (AHA) guidelines encourage the use of continuous waveform capnography to optimize chest

compressions during cardiopulmonary resuscitation (CPR). Effective chest compressions lead to an immediate rise in $ETCO_2$ as a result of effective pulmonary circulation (**Fig. 11.5**). $ETCO_2$ <10 mm Hg signals ineffective circulation despite CPR or a prolonged arrest with poor prognosis. Return of spontaneous circulation (ROSC) is unlikely if $ETCO_2$ persists with <10 mm Hg after correct tube placement and optimal CPR. An abrupt increase in $ETCO_2$ to normal values (>30 mm Hg) during CPR is an early indicator of ROSC and often precedes other clinical signs. Be aware that intravenous bicarbonate administration liberates CO_2 and causes a transient rise in $ETCO_2$, which should not be misinterpreted as optimized CPR or ROSC.

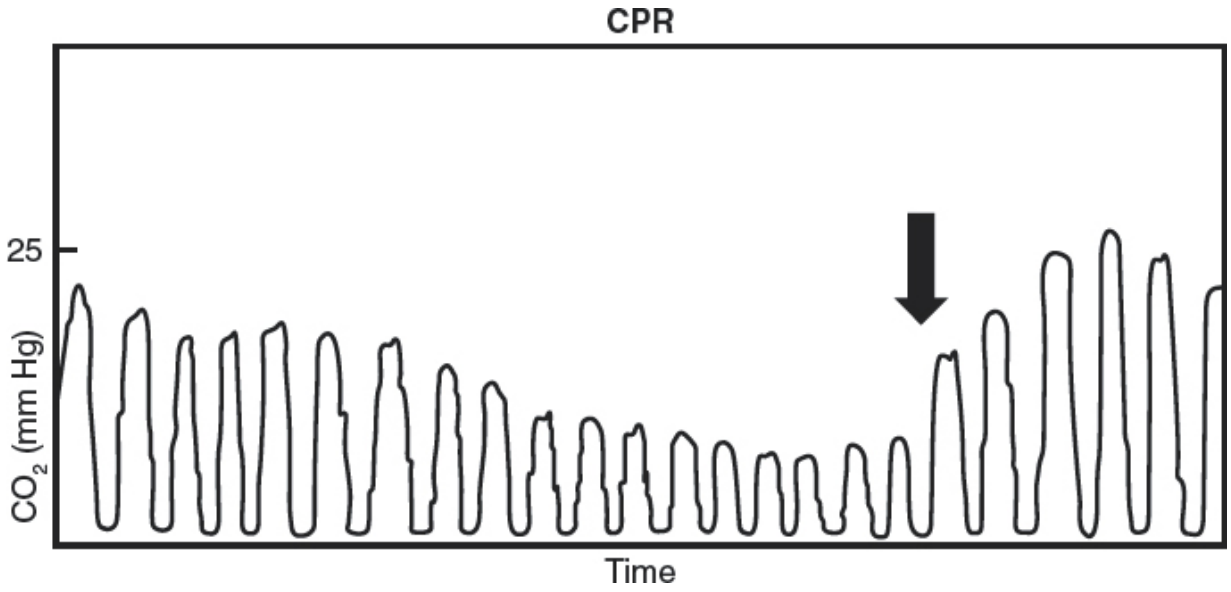

Figure 11.5: Capnography waveform during cardiopulmonary resuscitation (CPR) displayed at a low recording speed for trend analysis. $ETCO_2$ values during CPR are closely correlated with circulation. This trend waveform shows an increase in $ETCO_2$ with improved chest compressions (arrow). Return of spontaneous circulation (ROSC) also results in an abrupt rise in $ETCO_2$.

Monitoring Ventilation During Procedural Sedation

In the setting of procedural sedation, capnography is the most sensitive indicator of hypoventilation and apnea. Several studies show that patients undergoing procedural sedation have a high rate of acute respiratory events including hypoventilation and apnea, and clinical assessment of chest rise is not sensitive for detecting these events. Oxygen desaturation is a late finding in hypoventilation, especially in patients receiving supplemental

oxygen. For example, this is the premise behind apnea tests for brain death determination—apply supplemental oxygen so oxygen desaturation does not occur while hypercapnia accumulates because of apnea. Addition of capnography to standard monitoring provides advanced warning and reduces hypoxic events.

When using capnography to assess for respiratory depression, it is important to understand that hypoventilation can result in an increase or decrease in $ETCO_2$. Capnographic evidence of respiratory depression includes $ETCO_2$ >50 mm Hg, a change of $ETCO_2$ of 10% from baseline (or absolute change of 10 mm Hg), or loss of waveform. Bradypneic (classic) hypoventilation results in a waveform of increased amplitude and width (**Fig. 11.6**). Hypopneic hypoventilation (shallow ineffective breathing) results in a low-amplitude waveform, despite rising alveolar CO_2 (**Fig. 11.7**). In this case, the measured $ETCO_2$ value will decline because of the relative decrease in the volume of exhaled gas relative to the fixed volume of dead space gas, thus diluting the CO_2 in the sample as indicated.

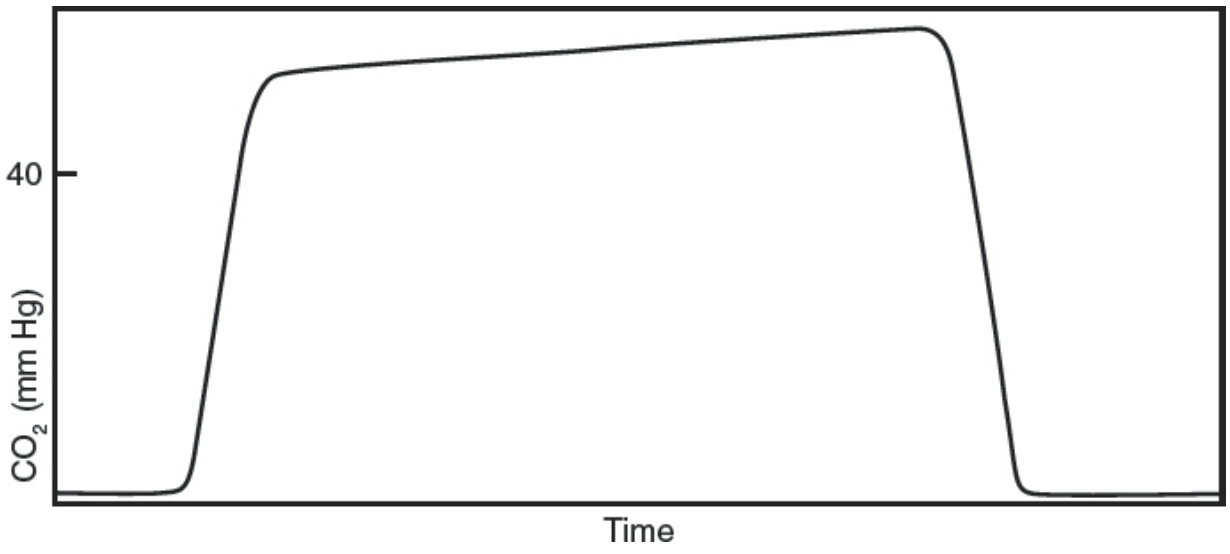

Figure 11.6: Bradypneic (classic) hypoventilation. Note that the waveform is wide and has increased amplitude, with an $ETCO_2$ >50 mm Hg.

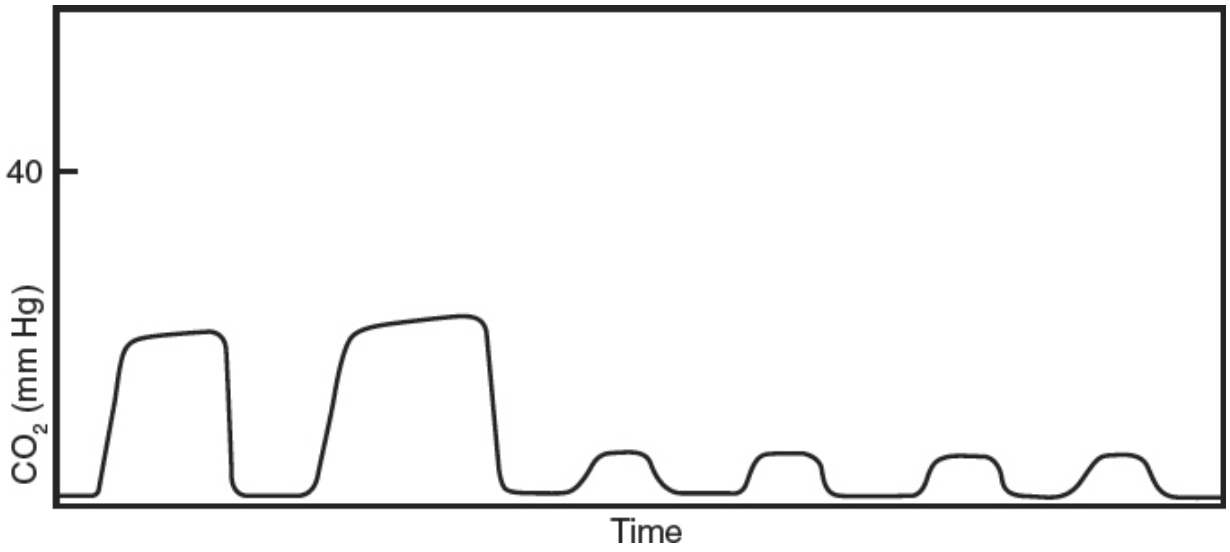

Figure 11.7: Hypopneic hypoventilation. Very shallow breathing results in a low-amplitude waveform and a low $ETCO_2$, despite a rising alveolar CO_2.

Analogous to its use in procedural sedation, capnography can be used to gauge adequacy of spontaneous ventilation whenever there is a concern for respiratory depression, similar to that in patients with depressed mental status caused by disease, trauma, or pharmacologic agents.

Surveillance and Monitoring of Mechanically Ventilated Patients

Capnography is useful for determining the adequacy of ventilation in mechanically ventilated patients and for monitoring for accidental extubation during movement (eg, patient turns for procedures, during computed tomography imaging, or during transfer). Although $ETCO_2$ can be an unreliable gauge of $PaCO_2$ because of variation in alveolar-arterial gradient, $ETCO_2$ can be incorporated as a surrogate for $PaCO_2$ to minimize routine blood gas analysis. An initial ABG sample allows comparison of $PaCO_2$ and $ETCO_2$ and establishes calibration so that $ETCO_2$ monitoring provides a continuous gauge of $PaCO_2$, assuming no major clinical change in patient condition. This is especially helpful for maintaining normocapnia in intubated patients who may be harmed by hypercapnia or hyperventilation, such as those with intracranial hypertension or brain injury.

Assessment and Monitoring of Patients in Respiratory Distress

Capnography can be useful for monitoring patients presenting with respiratory distress. A large pulmonary embolism can cause a decrease in $ETCO_2$ because of a lack of pulmonary perfusion, and many patients with severe respiratory distress are hypercapnic. Chronic obstructive lung disease and bronchospasm display a characteristic waveform with a slurred upstroke. The waveform shape may normalize with treatment of the underlying disease. Increasing $ETCO_2$ usually indicates worsening of respiratory distress and decreasing $ETCO_2$ usually indicates improvement of respiratory distress. $ETCO_2$ values and waveform trends may help guide management decisions, such as ET intubation or intensive care observation, in patients with respiratory distress from any etiology.

EVIDENCE

What key points of pulse oximetry monitoring are particularly pertinent during emergency airway management?

Rapid change in oxygen saturation is common during airway management. Although pulse oximetry is continuous, there is a delay in peripheral cutaneous oximetry relative to central SaO_2. Monitor averaging, probe location, circulatory and oxygenation status, and rate of desaturation all contribute to the degree of correlation. Sensor anatomic location is an easily modifiable factor: Forehead probes are closer to the heart and respond more quickly than distal extremity probes. Although most sensors lose reliability during hypotension, hypoperfusion, and hypothermia, forehead reflectance probes maintain reliability during these conditions in most patients.[1-3] As such, they are often preferred in the management of critically ill patients.[4,5]

Can ETO_2 monitoring be useful to monitor preoxygenation?

ETO_2 values can reflect the alveolar oxygen concentration, and therefore can help assess the percentage of oxygen that has been replaced with nitrogen within the lungs. ETO_2 values >85% usually indicate optimal preoxygenation. A single-center ED study showed that when clinicians were blinded to ETO_2 values, only 25% achieved this degree of preoxygenation.[6] In a follow-on study where clinicians could see ETO_2 values and make adjustments to preoxygenation based on this information,

67% of patients achieved optimal preoxygenation.[7] ETO_2 seemed to be most useful when using a bag valve mask for preoxygenation, because small mask leaks threaten adequate preoxygenation. These studies highlight a possible role for ETO_2 monitoring during preoxygenation, though further research is needed to assess the utility of ETO_2 in different preoxygenation strategies and determine its association with patient-centered outcomes.

Is there evidence for the use of capnography in emergency settings?

The 2020 AHA advanced cardiovascular life support (ACLS) guidelines recommend the use of capnography for confirmation of correct tube placement, monitoring CPR quality, and indicating ROSC. Continuous waveform capnography is recommended, in addition to clinical assessment, as the most reliable method of confirming and monitoring correct placement of an ET tube.[8] If continuous waveform capnometry is not available, a non-waveform CO_2 detector is a reasonable alternative.[8] Colorimetric detectors are less accurate for confirming correct tube placement during cardiac arrest. However, colorimetric and non-waveform capnometers are nearly 100% accurate for confirming correct tube placement in patients with circulation.[9] AHA guidelines also recommend waveform capnography to optimize CPR performance.[8] ROSC is unlikely when $ETCO_2$ values are persistently <10 mm Hg in intubated patients receiving good quality CPR.[10] A sudden increase in $ETCO_2$ to normal values (>30 mm Hg) during CPR is an early indication of ROSC.[11] The use of waveform capnography during procedural sedation is well accepted and recommended as a standard for the safe practice of anesthesia worldwide.[12] Although it is not used in some EDs, there is good evidence that waveform capnography is the most sensitive early indicator of hypoventilation and apnea, and its use has been shown to decrease the incidence of hypoxia during ED procedural sedation.[13-16]

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Section III

Basic Airway Management

12 Bag-Mask Ventilation
13 Extraglottic Devices
14 Managing the Patient With an Extraglottic Device in Place

CHAPTER 12

Bag-Mask Ventilation

Robert F. Reardon

Steven C. Carleton

INTRODUCTION

Expertise at bag-mask ventilation (BMV) is a fundamental skill of emergency airway management. BMV is the initial mode of ventilation for patients with inadequate respiratory drive or apnea and the first line of rescue when rapid sequence intubation (RSI) or other airway techniques fail. Disposable self-inflating resuscitation bags are ubiquitous and often the only available equipment in the initial moments of an unexpected airway emergency. Difficult BMV is relatively common in emergency settings, but providers who are highly skilled can confidently manage these airways and avoid disaster. Unfortunately, BMV is often delegated to relatively inexperienced providers, and most health care providers believe they are proficient at BMV, so they spend little time and effort trying to improve their skill. Providers who want to master BMV must anticipate difficulty, employ optimal technique, monitor and adjust constantly, and utilize a checklist for troubleshooting.

BAG-VALVE-MASK DEVICES

This chapter will focus on the use of disposable bag-valve-mask (BVM) devices with self-inflating bags (**Fig. 12.1**), which were a breakthrough for emergency airway management owing to their ease of use. These are distinct from free-flow or flow-inflating “anesthesia” bags used primarily in surgical suites and neonatal resuscitation, which require high oxygen flow and a near-perfect mask seal to effectively ventilate. All resuscitation bags are designed to ensure the patient is delivered 100% oxygen from the

reservoir while “exhausting” exhaled gas into the room through a series of one-way valves. Valve configurations vary by manufacturer. Generally, there is a duck-bill inspiratory valve that, when forced open by squeezing the bag or patient inhalation, provides 100% oxygen from the bag’s reservoir. During forward gas flow, the exhalation valve closes, limiting room air entrainment. During exhalation, the opposite occurs, and the duck-bill valve pinches closed to prevent regurgitation of CO_2 into the reservoir, whereas the exhalation valve opens, thereby venting exhaled gas into the room. The first self-inflating resuscitation bag was invented by Henning Ruben and Holger Hesse in Copenhagen, Denmark, in 1956, and manufactured by Testa Laboratory. They named the device “AMBU” (Air Mask Bag Unit) and later changed the name of the company to Ambu; the name “AMBU” became synonymous with the self-inflating resuscitation bag. Disposable BVM devices are available in adult (1500-2000 mL), pediatric (450-900 mL), and neonatal (220-320 mL) sizes. Self-inflating bags are designed for ventilation of apneic patients and are not ideal for delivering high-flow oxygen to spontaneously breathing patients (see Evidence section). They also do not provide the same degree of provider feedback on compliance that free-flowing bags provide.

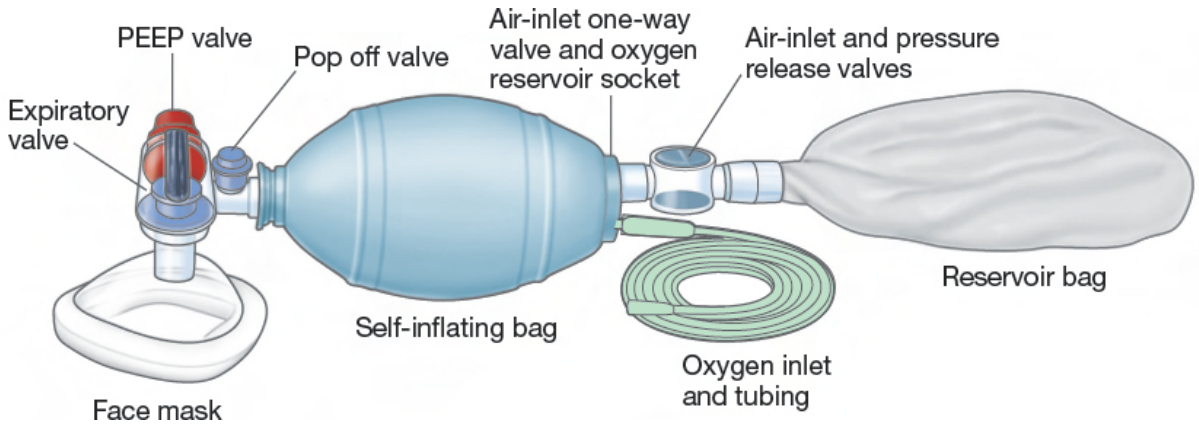


Figure 12.1: Modern adult bag-valve-mask unit.

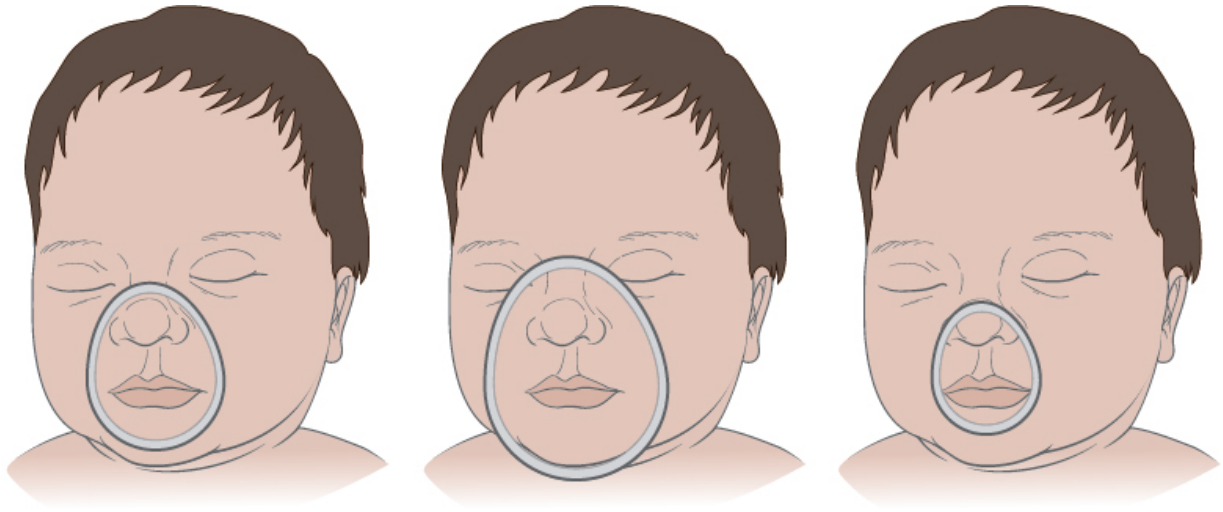
FACE MASK VENTILATION TECHNIQUE IN THE EMERGENCY SETTING

Many providers initially learn mask ventilation (MV) techniques in the operating room setting, where the incidence of difficult MV is low and one-

handed techniques are common. This does not always translate well into emergency settings, where difficult MV should be anticipated and one-handed techniques are discouraged. Critical components of optimal face MV include (1) selecting appropriate-sized equipment; (2) optimizing the face mask seal with a grip that allows for maximal mandibular advancement; (3) head and neck positioning to open the upper airway; (4) using oral and/or nasal airways; (5) neuromuscular blockade when needed; (6) attention to volume, pressure and rate; (7) application of positive end-expiratory pressure (PEEP); (8) ongoing assessment of BMV adequacy; and (9) troubleshooting of difficult BMV.

Optimizing Face Mask Seal

Creating an adequate mask seal without leaks involves using the correct mask size and ensuring continuous contact between the mask and facial structures. The cuff on the mask is intended to seat on the bridge of the nose the malar eminences of the maxillae, the maxillary and mandibular teeth, the anterior body of the mandible, and the groove between the chin and the alveolar ridge of the mandible (**Fig. 12.2**). This ensures that the mouth and nose will be covered entirely and that the cuff will be supported by bony structures.



A **Correct.** Covers mouth, nose, chin, but not eyes.

B **Incorrect.** Too large. Covers eyes, and extends over chin.

C **Incorrect.** Too small. Does not cover nose and mouth well.

Figure 12.2: Proper face mask placement. Spreading the cuff of the mask before seating it on the face to improve the mask seal. Using the proper mask size is important, but it is better to use a mask that is too large than one that is too small.

In general, the seal between the mask and the face is least secure laterally over the cheeks. This is particularly true in edentulous patients, whose unsupported soft tissue of the cheeks may incompletely contact the cuff. In this circumstance, adequate facial support for the cuff can be maintained by leaving dentures in place during BMV or restored by packing gauze rolls into the cheeks. Medial compression of the soft tissue of the face against the outside margins of the cuff can also mitigate leakage. Shifting the mask such that the caudal edge of the cuff rests inside the lower lip may improve the seal between the mask and the face in edentulous patients.

The mask should not be pushed down onto the patient's face during BMV, but, rather, the patient's face is pulled upward into the mask. This has significant implications for the most effective method of holding the mask after the initial seal is obtained. As discussed in the following section, a two-handed and two-person technique employing a thenar mask grip should be used whenever possible.

Face Mask Grip That Allows Maximal Mandibular Advancement—Thenar Grip

Functional occlusion of the airway is common in supine, obtunded patients, particularly when neuromuscular blocking agents (NMBAs) have been given. Functional occlusion results from posterior displacement of the tongue onto the posterior oropharynx wall as the genioglossus, geniohyoid, and hyoglossus muscles relax (**Fig. 12.3**). Mandibular advancement overcomes the functional occlusion of the upper airway and is the best way to open the upper airway in an unconscious or paralyzed patient (**Fig. 12.4**).

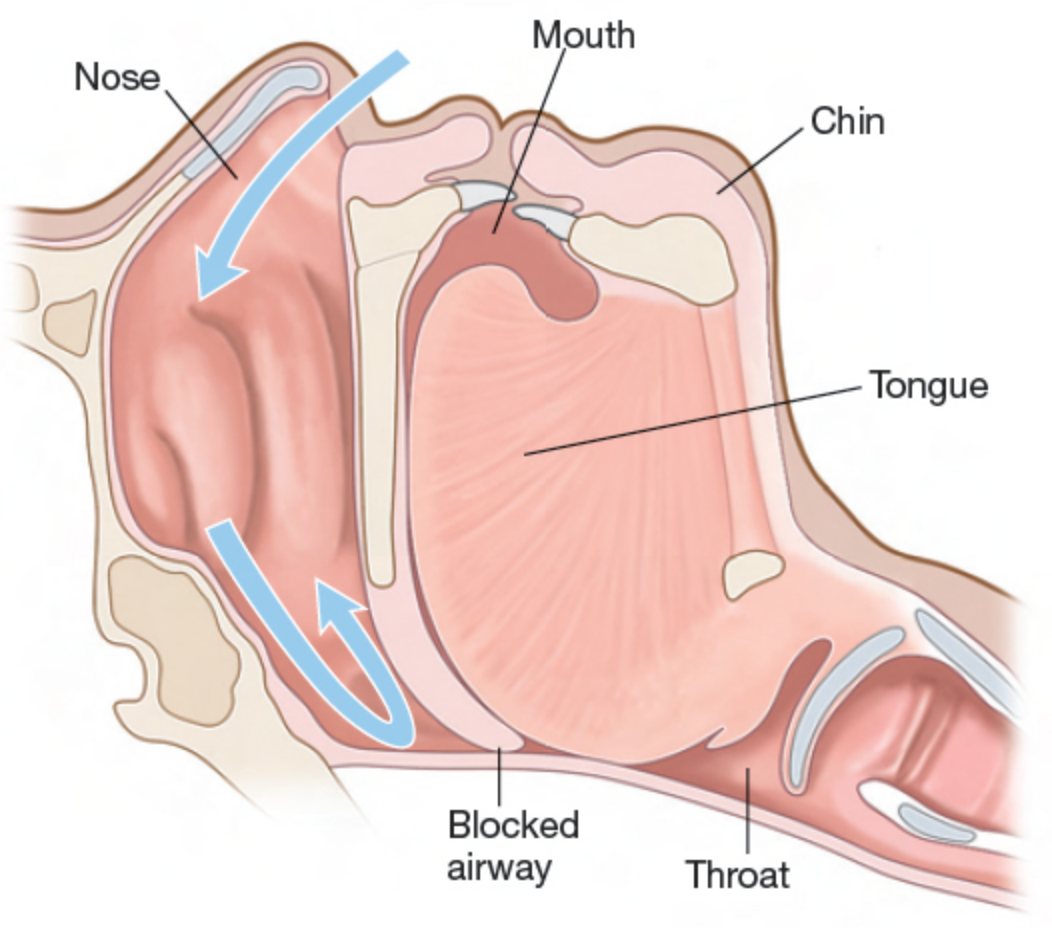


Figure 12.3: Functional occlusion of the upper airway in an unconscious or paralyzed patient.

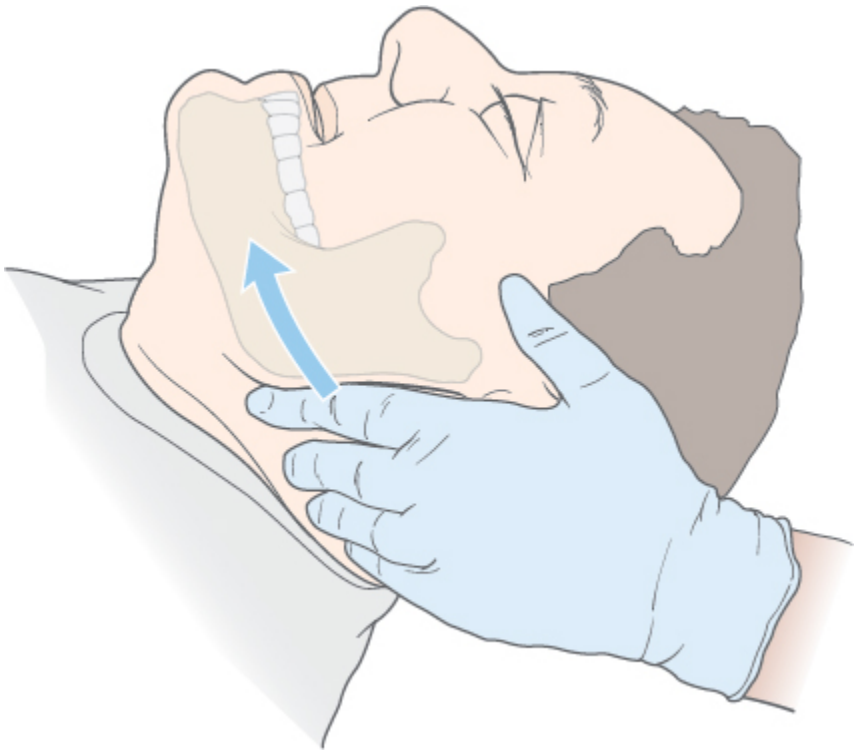


Figure 12.4: Mandibular advancement (or jaw thrust). It is useful to think of this maneuver as “creating an underbite,” with the bottom incisors placed anterior to the upper incisors. This is the best way to open the upper airway and can be safely performed without cervical spine movement in blunt trauma patients.

The face mask grip that allows maximal mandibular advancement is the thenar grip. The thenar grip is performed by aligning the fingers toward the floor and placing the tips of the middle fingers behind the angle of the mandible (**Fig. 12.5**). It is referred to as the thenar grip because the body of the mask is held in place by the strong thenar eminence of the hands, which frees up four fingers to perform mandibular advancement. This technique can be performed from the head of the bed (Fig. 12.5A) or from the patient’s side (Fig. 12.5B). This technique is significantly different from the face mask grips that are traditionally taught, which do not allow maximal mandibular advancement.

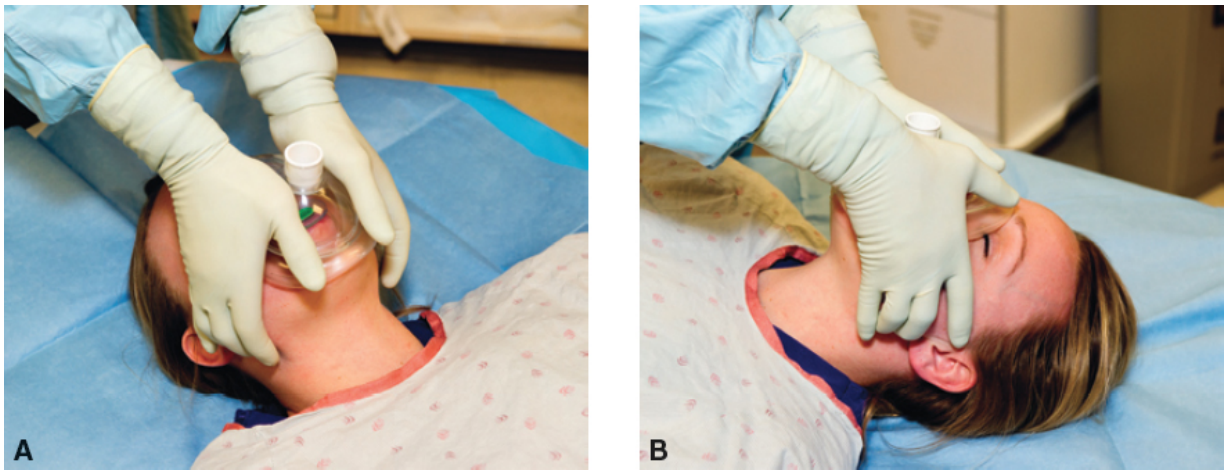


Figure 12.5: Thenar mask grip. This is the only mask grip that allows maximal mandibular advancement and should be the "go to" face mask grip in emergency care settings. It can be performed from the head of the bed (A) or from the patient's side (B).

Traditional Single-Handed Mask Grip

In the one-handed technique, the operator's dominant hand is used to hold and compress the bag, whereas the nondominant hand is placed on the mask, with the thumb and the index finger partially encircling the mask connector, as if making an "OK" sign. This grip is also referred to as the "EC grip," because the third through fifth fingers form the letter "E" and grasp the patient's mandible, whereas the thumb and index finger form the letter "C" while grasping the mask (**Fig. 12.6A**). With a one-hand mask grip, it is virtually impossible to perform mandibular advancement. It was developed for anesthesiologists providing inhalational anesthesia to spontaneously breathing patients and does not perform well for providing positive pressure ventilation to patients with hypoventilation or apnea. For this reason, the traditional one-hand face mask grip technique should not be used during emergency airway management unless there is no other choice (no assistant available to squeeze the bag). In this scenario, it may be better to place an extraglottic device (RGD) and attach the patient to a ventilator (see Chapter 13), rather than perform suboptimal BMV.

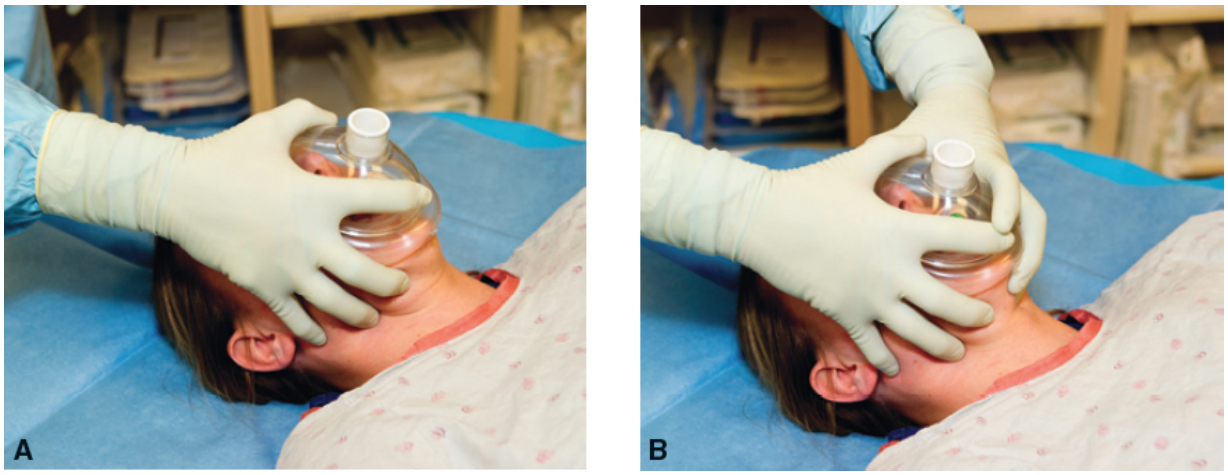


Figure 12.6: A: Single-handed mask hold with the “EC” grip. B: Two-handed mask hold with the conventional, double “ED” grip.

Traditional Two-Handed Mask Grip

Two-handed mask hold techniques are much more effective for delivering adequate ventilation to apneic patients, especially in emergency settings. Holding the mask with two hands allows the provider to make a better mask seal and perform proper mandibular advancement. The traditional two-handed technique is just a two-handed CE technique (**Fig. 12.6B**), but with this technique the operator’s fingers are on the body of the mandible and cannot perform maximal mandibular advancement. Although data are mixed, multiple studies have shown that ventilation volumes are larger and the risk of ventilation failure lower with the thenar grip (see Evidence section).

Head and Neck Maneuvers to Open the Upper Airway

A patent airway permits the delivery of appropriate tidal volumes with the least possible positive pressure. Functional occlusion of the airway is common in supine, obtunded patients, particularly when NMBAs have been given. Occlusion results from posterior displacement of the tongue onto the posterior oropharynx wall as the genioglossus, geniohyoid, and hyoglossus muscles relax. Airway closure may also result from occlusion of the hypopharynx by the epiglottis, or by circumferential collapse of the hypopharynx when airway tone is lost. Airway collapse is exacerbated by flexion of the head on the neck and by widely opening the mouth.

Optimal head and neck positioning for BMV is the same as for direct laryngoscopy. Achieving the best position will require different movements depending on the patient's size and shape. The most important single parameter for assuring upper airway patency is alignment of the external auditory canal (EOC) and the sternal notch. A normal size thin adult will require about 7 to 10 cm of head elevation to achieve alignment of the EOC and sternal notch. This results in about 30° of flexion of the lower cervical spine (C6-7) and extension of the head (atlanto-occipital joint, C1-2) (**Fig. 12.7A**). This is also known as the "sniffing position." In an obese patient, this will require significant ramping under the shoulders and neck to achieve this position (**Fig. 12.7B**).

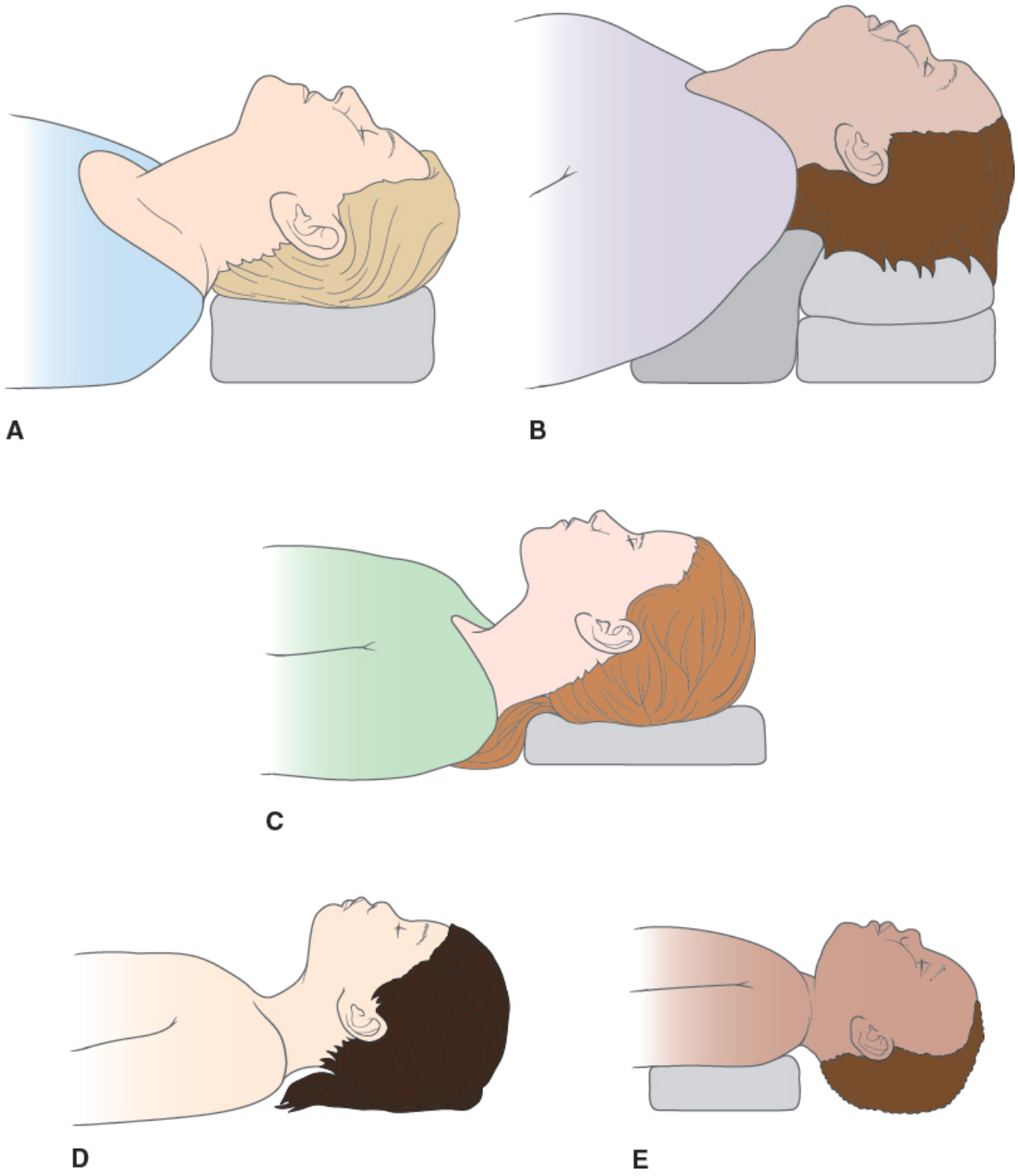


Figure 12.7: Optimal head and neck position for opening the upper airway. A: Normal size adult. B: Morbidly obese adult. C. 8-year old child. D. 3-year-old child. E. Newborn child.

In children, the amount of head elevation will vary depending on the child's age. Small children may not need any head elevation, and older children will need more head elevation (**Fig. 12.7C** and **D**). Newborns and

infants have large occiputs and will therefore need elevation of their torso relative to their head in order to align the EOC and sternal notch (**Fig. 12.7E**). In preschool children (ages 1-5), neutral or slight head extension (0-13°) is best, and in school-age children (ages 6-10) the optimal head extension is about 16°. The most common mistakes in children are failure to align the EOC and sternal notch and overextension of the head (atlanto-occipital joint).

Oral and Nasal Pharyngeal Airways

Oropharyngeal airways (OPAs) and nasopharyngeal airways (NPAs) help to prevent dynamic upper airway obstruction by the tongue and maintain a patent airway in unconscious or paralyzed patients. OPAs generally facilitate airway maintenance more reliably than NPAs, but NPAs are better tolerated in patients with intact gag and cough reflexes. Both are underutilized in emergency airway management. Use one or more of these adjuncts whenever difficult BMV is encountered. When airway patency during BMV is difficult to maintain with an OPA alone, it may require two NPAs. Sizing is critical because an OPA or NPA that is too large or too small may paradoxically lead to airway obstruction.

The proper size of OPA should reach externally from the midline of maxillary incisors to the angle of the mandible (**Fig. 12.8A**). Size 8 is appropriate for most women and size 9 for most men. They are intended to extend from the central incisors to just short of the epiglottis and posterior pharyngeal wall. Two methods of insertion are commonly used for OPAs. In one, the OPA is inserted into the open mouth in an inverted position with its tip sliding along the palate. As the insertion is completed, the OPA is rotated 180° into its final position, with the flange resting against the lips. This method is designed to minimize the likelihood of the OPA impinging the tongue and displacing it posteriorly. In the second method, the tongue is pulled forward manually, and the OPA is inserted with its curve paralleling that of the airway until the flange rests against the lips.

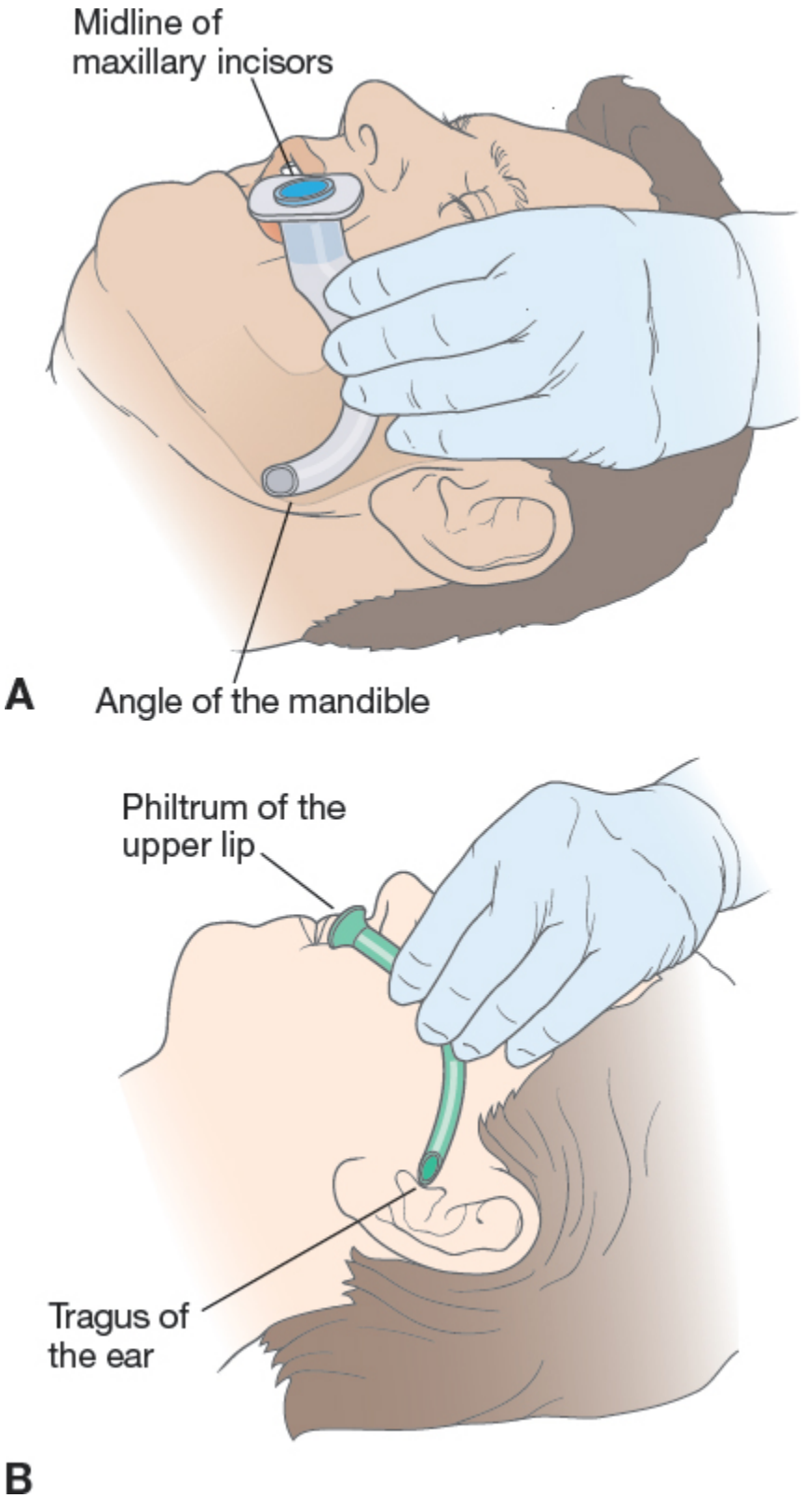


Figure 12.8: Proper sizing of oral and nasal airways. A: OPA should reach externally from the midline of maxillary incisors to the angle of the mandible. Size 8 is appropriate for most

women and size 9 for most men. B: NPA should reach externally from the philtrum of the upper lip to the tragus of the ear. Size 6 is appropriate for most women and size 7 for most men.

The proper size of NPA should reach externally from the philtrum of the upper lip to the tragus of the ear (**Fig. 12.8B**). Size 6 is appropriate for most women and size 7 for most men.

NPAs should be well lubricated and inserted through the inferior nasal meatus parallel to the palate until the flange rests at the nostril. When introducing an NPA, the recommended position is with the point of the nasal trumpet away from the anterior nasal septum (bevel side facing medially) in order to reduce injury to Kiesselbach plexus and reduce the risk of epistaxis. If resistance is met, either the tube should be downsized or insertion should be attempted through the contralateral nostril. Relative contraindications include bleeding diathesis and suspected basilar skull fracture.

Neuromuscular Blockade to Facilitate BMV

Traditional teaching was that providers should never give an NMBA until after demonstrating that the patient can be successfully mask ventilated. However, there is now evidence showing that neuromuscular blockade can improve MV success and rarely makes it more difficult. The circumstance in which NMBAs would be used to facilitate BMV would be in a patient with sudden acute respiratory arrest, where he or she does not have adequate respiratory drive to stay alive but still enough muscle tone to interfere with airway opening maneuvers and positive pressure ventilation. Unless owing to an immediately reversible condition (ie, heroin overdose), these patients will all get intubated, and, therefore, administering RSI medications to ease difficult oxygenation and MV, while intubation preparations are being finalized, is a reasonable strategy. An additional benefit of using neuromuscular blockade in this setting is that it will help facilitate placement of an EGD if BMV is impossible.

Ventilation Parameters for Bag-Mask Ventilation

Proper ventilation involves delivery of an appropriate tidal volume, peak pressure, and rate to minimize complications.

Volume

Overzealous volume and pressure delivery easily exceed the opening pressures of the upper and lower esophageal sphincters (approximately 20-25 cm H_2O pressure), insufflating gas into the stomach, which increases the risk of regurgitation and aspiration as well as loss of functional residual capacity as the stomach distends and compresses the diaphragms. Larger volumes will also have a greater negative impact on venous return and cardiac output in vulnerable patients with poor volume status and cardiac function. It does not help that self-inflating resuscitation bag volumes are not standardized and far exceed desired tidal volumes for most patients. The goal for most patients is 5 to 8 mL / kg of ideal body weight, approximately 400 mL in an average adult. Some have advocated using pediatric resuscitation bags for adult patients to minimize the risk of excessive ventilation. Although this may be more relevant in stabilized intubated patients, there are no clinical studies to support this practice in the setting of emergency airway management of a decompensated critically ill or injured patient and could result in inadequate tidal volumes (see Evidence section).

Pressure

Factors that increase peak inspiratory pressures include shorter inspiratory times, larger tidal volumes, incomplete airway opening, increased airway resistance, and decreased lung or chest compliance. Several of these factors are controllable, and attention should be paid to maintenance of airway patency, delivery of inspiration over a 1- to 2-second period, and limiting tidal volume to that sufficient to produce subtle chest rise per minute over 1 to 2 seconds each. Some advocate the routine use of pressure limiting pop-off valves, but this may result in the inability to properly ventilate patients with intrinsically high airway pressures (see Evidence section).

Rate

The proper rate for MV should target the age and condition appropriate to minute ventilation after ensuring appropriate tidal volumes. Excessive ventilation rates lead to dead-space ventilation, breath-stacking and hypocarbia (respiratory alkalosis). CO_2 levels are directly correlated with cerebral blood flow, and outcomes in patients with traumatic head injury have been consistently shown to be worse when patients are overventilated.

Also, a standard rate for an adult patient in cardiac arrest is 10 breaths per minute, but overventilation during cardiac arrest is common, so counting out loud or using a timing light is helpful in this situation. It is also important to remember that some patients (infants, those with severe acidosis) need higher respiratory rates, so determining the appropriate rate based on the patient and situation is critical.

Assessing Adequacy of Bag-Mask Ventilation

The provider squeezing the self-inflating resuscitation bag should simultaneously feel for the resistance of the bag to compression and observe the patient's chest for subtle rise and fall during ventilation. This feedback can provide clues about the patient's lung and chest wall compliance and can influence bagging technique in response. Other more objective signs of satisfactory ventilation are capnography and maintenance of adequate oxygen. Waveform capnography is the best way to assess adequacy of BMV, because it gives breath-to-breath information about ventilation status and rate, so that problems can be corrected immediately. Decreasing oxygen saturation is a late marker of poor BMV. A simple scoring method using the shape and values of the capnography waveform has been proposed as the optimal method of assessing successful BMV (**Fig. 12.9**).

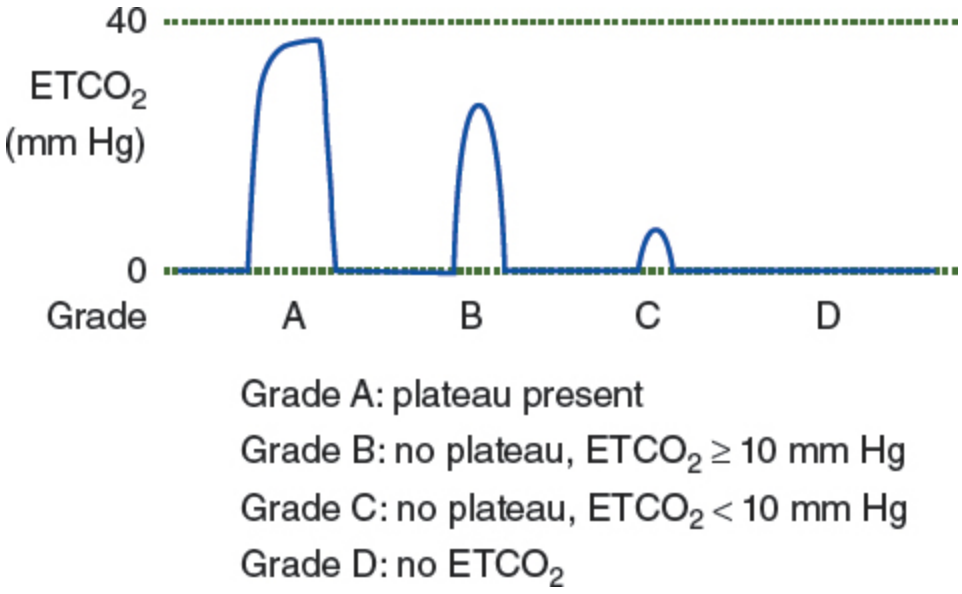


Figure 12.9: Use of continuous capnography to objectively grade the adequacy of BMV. Waveform B indicates the presence of mask leak. (Republished with permission of Elsevier,

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Stomach Inflation, Sellick Maneuver, and Aspiration Risk With BMV

Stomach inflation is a complication of BMV that may be unavoidable, but efforts should be made to reduce it if possible. Patients who have prolonged BMV and those who are ventilated with higher tidal volumes and higher pressure—including those with asthma, other lung pathology, and obesity—are more likely to have stomach inflation. Using the approaches discussed previously to mitigate overventilation will help to limit stomach inflation. Studies demonstrate that the application of cricoid pressure (Sellick maneuver) to occlude the esophagus against the anterior vertebral bodies during BMV may reduce gastric insufflation. If resources permit, consider applying gentle cricoid pressure—a force just enough that it would cause pain if applied to the bridge of your nose—during BMV in unresponsive patients. Pressure should be abandoned immediately if high pressures/resistance is encountered, and once laryngoscopy begins.

DIFFICULT AND IMPOSSIBLE MASK VENTILATION

The incidence of difficult MV is 1% to 15% in elective surgical patients, depending on the definition, but likely much higher in emergency airway settings. Impossible face MV is rare in elective anesthesia patients but is more common in the emergency department patients. The best ways to deal with difficult or impossible MV are to predict it, employ optimal technique, have a troubleshooting plan, and move early to alternatives such as an EGD. Difficult MV may be attributable to technique-related factors that can be modified, such as using an improper mask size, suboptimal positioning, lack of adjuncts, or patient factors that cannot be modified but that can be predicted and mitigated. Using a checklist (see below) to quickly identify correctable problems is the best way to troubleshoot difficult BMV.

Predicting Difficult or Impossible BMV

The following factors are well known to be associated with difficult BMV:

1. Male gender
2. Beard
3. Limited neck movement
4. Advanced age (>45 years)
5. Obesity
6. Short thick neck
7. Mallampati grade 3 or 4
8. Limited mandibular advancement
9. Short thyromental distance (<6 cm)
10. Lack of teeth
11. Sunken cheeks
12. History of snoring
13. History of radiation to the neck

In addition to the preceding factors, patients who have underlying lung pathology that require high inspiratory pressures are at higher risk for a mask leak as well as stomach inflation and aspiration. Trauma patients are more difficult because they are usually kept in a neutral spine position rather than a sniffing or ramped position, and blood or direct injuries to the face may impact mask seal. Hard cervical collars—if utilized—should be opened in the front to allow mandibular advancement. Pediatric patients are especially at risk for stomach inflation that limits tidal volume and can rapidly make MV nearly impossible. In adults, the most significant clinical predictor of impossible MV is a history of neck radiation.

Optimal Technique and Troubleshooting Difficult BMV

Not all patients require optimal technique to achieve adequate ventilation and oxygenation, but MV should never be considered difficult or impossible unless optimal technique has failed. Although providers often focus on the saturation, the first question to ask is *whether ventilation is occurring* by assessing bag compliance, lung rise, and capnography. Use the checklist in Table 12.1 for rapid troubleshooting of ventilation. If *saturation is inadequate in the setting of good ventilation* the focus needs to be on

ensuring oxygen flow, employing PEEP and recruitment maneuvers, effective reservoir, and treating lung pathology (**Table 12.1**).

TABLE 12.1 Checklist for Optimizing Bag-Mask Ventilation

Checklist for Optimizing mask VENTILATION:

1. Appropriately sized equipment
2. Optimal face mask seal with maximal mandibular advancement
   a. One person dedicated to mask with thenar grip
   b. Visible/audible leak
   c. Check capnography waveform
3. Optimal ear-to-sternal notch positioning
4. Oral and/or nasal airways in place
5. Consider treatable lung pathology
   a. Tension pneumothorax (PTX)
   b. Asthma
6. Consider neuromuscular blockade
7. Maximal oxygen flow, PEEP, adequate oxygen reservoir
8. Equipment failure, pop-off valve, or open port

EXPERIENCE, TRAINING, AND THE LEARNING CURVE FOR BMV

Lack of experience is often a factor in difficult BMV. When BMV is inadequate or impossible in the emergency setting, the most experienced provider should take over immediately. Unfortunately, in many emergency settings there may not be a more experienced provider. This highlights the need for emergency care providers to practice optimal BMV skills with two-handed thenar eminence grip whenever possible. Whether BMV training or practice occurs in a clinical setting or on cadavers or manikins, the goal should be to practice optimal BMV using the preceding checklist. Training required to achieve minimal expertise in BMV in elective operative patients is 25 procedures (see Evidence section), and the number needed to achieve expertise in the emergency setting is likely much higher. As noted in the introduction, most health care providers mistakenly think that they are proficient at BMV, so they spend little time and effort

practicing or trying to improve their skill level. Those responsible for training emergency medicine personnel should consider whether their trainees are proficient at BMV and look for all possible opportunities to practice this vital skill (see “BMV during apneic period of RSI” in the Evidence section).

SUMMARY

BMV is one of the most important skills for emergency airway management. Emergency medical providers should do everything possible to improve their skill level, always provide optimal BMV, and know how to predict and troubleshoot difficult BMV.

EVIDENCE

Do BMV devices function well in spontaneously breathing patients?

BMV devices are designed to ventilate and deliver 100% F_{IO_2} to apneic patients and often perform poorly when used to “assist” spontaneously breathing patients. There have been several studies showing that BVM devices often fail to deliver high-concentration oxygen to spontaneously breathing patients.[1-7] Unless there is a perfect mask seal (which is unlikely), spontaneously breathing patients inhale room air around the mask and end up getting a low concentration of oxygen. In the operating room setting, a face mask is commonly used to deliver 100% F_{IO_2} using an anesthesia machine, which allows delivery of flush-rate oxygen (≥40 L/min), compensating for a poor mask seal. This does not work well with a BMV device, and a poor mask seal results in delivery of low-concentration oxygen.[8,9] In addition, several studies show that using a BVM device for spontaneously breathing patients increases the work of breathing, especially with increasing minute ventilation and the addition of PEEP.[10-12] When spontaneously breathing patients need high-concentration oxygen, it is best to use bilevel positive airway pressure (BiPAP), continuous positive airway pressure (CPAP), high-flow nasal canula (HFNC), or a nonrebreather (NRB) mask with flush-rate oxygen.[9,12-14]

Is there evidence for using a PEEP valve with a BVM device?

Although this is common practice, there is little evidence to guide the practice. Several studies show that when a disposable PEEP valve is added to a neonatal self-inflating resuscitation bag, the results are inconsistent.[15-18] With some setups, PEEP valves work properly, but with others PEEP pressure is rapidly lost, and desired pressures are not accurately delivered.[15,16,18] The 2010 International Liaison Committee for Resuscitation (ILCOR) recommendations for newborn resuscitation suggests that self-inflating bags (SIBs) with PEEP valves "often deliver inconsistent end-expiratory pressures."[19] There is no published evidence to guide the practice of using PEEP valves with BVM devices in adults. At the same time, PEEP valves are unlikely to cause harm and should be trialed if PEEP is thought to be needed in the context of difficult MV.

How does neuromuscular blockade affect BMV?

Traditional teaching was that patients should not be paralyzed prior to successful BMV, but patients with acute respiratory arrest often have muscle tone that interferes with airway opening maneuvers and positive pressure ventilation. This is distinct from the decision to administer NMBAs in spontaneously breathing patients who require emergency airway management, in whom RSI might be initially contraindicated if rescue MV is predicted to fail. There are several studies showing that paralysis with a neuromuscular blocker improves BMV.[20-25] Importantly, no patient in any of these studies became more difficult to ventilate via BMV after administration of a neuromuscular blocker. The study by Soltesz et al is the most interesting because they studied patients at high risk for difficult BMV and those known to be difficult to mask ventilate. They found that median tidal volumes increased from 350 to 600 mL after complete neuromuscular blockade. Many modern difficult airway algorithms recommend that a neuromuscular blocker be tried in the event that difficult BMV is encountered.[26,27]

Is it appropriate to perform BMV during the apneic period of RSI?

Traditional teaching called for no positive pressure ventilation during the apneic period of RSI unless critical desaturation occurred owing to concern for gastric insufflation and regurgitation. Casey showed that performing BMV between RSI induction and laryngoscopy improves oxygen

saturations and reduces the incidence of severe hypoxemia in the intensive care unit (ICU) without increased aspiration.[28] These results, however, are difficult to extrapolate to emergency populations. In this study, there were no standardized preoxygenation strategies, and patients deemed at high risk for aspiration were excluded. Additionally, virtually all patients were being intubated for hypoxemic respiratory failure, and, therefore, the risk-benefit ratio of interval bagging during RSI may not be the same for all ED patients. These findings could also be explained by poor preoxygenation efforts. In the ED, it is reasonable to perform careful, deliberate interposed MV when the clinician believes the risk of rapid desaturation outweighs the risk of aspiration. Regardless, this practice should not be a substitute for optimal preoxygenation.

Does head rotation improve BMV?

Some experts have long taught that head rotation improves face MV. There are two studies that address this issue, with conflicting results. Both studies were performed in anesthetized apneic adults in the operating room setting. One showed that 45° of lateral head rotation significantly increased tidal volume during face MV, and the other found no significant change with 30° of head rotation.[29,30] Therefore, it may be worth trying head rotation in cases of difficult BMV, but it cannot be strongly recommended.

Should cricoid pressure be applied during BMV?

If sufficient personnel are available, this technique may be advantageous, particularly during prolonged BMV. Proper application of cricoid pressure does appear to reduce the volume of air entering the stomach when BMV is performed with low to moderate inspiratory pressures.[31] Although a radiology study demonstrated that cricoid pressure may not reliably occlude the esophagus,[32] a recent clinical study showed the opposite.[33] Since cricoid pressure can cause airway obstruction, it should be released immediately if BMV is difficult.[34,35]

Are pop-off valves always good in the emergency setting?

No, pop-off valves are intended to prevent barotrauma in patients with normal lungs. In critically ill patients with high airway pressures, they will

prevent adequate ventilation. Some pediatric experts recommend that pop-off valves be routinely deactivated in emergency settings.[36,37]

Should we get rid of adult-size resuscitation bags?

Some have suggested replacing adult-size (≈1000 mL) resuscitation bags with pediatric-size (≈500 mL) bags.[38] There is currently not enough evidence to support this change. Although low pressure and low tidal volume ventilation is appropriate for most patients who are in cardiac arrest or in the ICU after initial resuscitation, emergency providers manage patients with a wide variety of anatomic and physiologic derangements, and it is likely that some of them need higher ventilation pressure and volume when they are in extremis. There are no clinical studies on using pediatric resuscitation bags for adults with a wide variety of airway emergencies. Extrapolating data from intubated patients in the operating room setting or from manikin studies may be misleading, and there is significant evidence that the volume delivered with BMV is often less than expected, especially with inexperienced operators.[39-41]

Is there evidence that the thenar grip is better than the traditional two-handed C-E grip?

In a study of anesthetized apneic patients in the operating room setting, the two-handed thenar eminence mask grip was shown to result in substantially greater ventilation volumes and fewer failed breaths compared to the traditional two-handed CE technique for MV by novices.[39] Another study compared the two-handed CE and thenar grips on anesthetized obese apneic patients with more experienced providers and showed similar results.[42]

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CHAPTER 13

Extraglottic Devices

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INTRODUCTION

Extraglottic devices (EGDs) are artificial airways that are inserted into the upper esophagus or hypopharynx, but not through the glottis, to provide a conduit of gas in and out of the lungs. Those that sit above the larynx are termed *supraglottic* devices (SGDs), whereas those that sit posterior to the glottis in the upper esophagus are termed *retroglottic* devices (RGDs).

Historically, these devices were used for elective surgery cases in fasted patients, but over time their key role in emergency airway management has been refined. Extraglottic devices are usually placed blindly and may be used as primary (alternative) or secondary (rescue) airways. Extraglottic airways are generally easier to utilize than face mask ventilation or endotracheal intubation and have been shown to provide a substantial, but not complete, degree of aspiration protection.

Cuff leak pressure, which is the pressure within the airway up to which the device prevents air leakage, varies depending on the device and fit. RGDs typically have higher cuff leak pressures (up to 35-40 cm H_2O) compared with SGDs (25-30 cm H_2O). This tighter seal may be advantageous in patients with intrinsic high airway resistance requiring high peak airway pressures (eg, asthma or obesity) or if glottic anatomy is distorted from hematoma, infection, or mass, requiring increased inflation pressure. These devices may also provide some tamponade effect for upper airway bleeding. There has been some concern from animal studies that

RGDs exert more pressure on the carotid vessels than do SGDs, but this not been supported in human studies.

For the purposes of emergency airway management, the ideal EGD would be inexpensive, easy to use, available in pediatric sizes, have a high first-attempt success for oxygenation and ventilation in a wide variety of clinical circumstances, allow gastric drainage, and serve as a conduit to the trachea for intubation. There are a number of products that meet these expectations; however, there is little research demonstrating the clear superiority of one specific device over another. The choice of which EGD to include in your airway supplies may come down to preference for specific features or to what is in common usage in other parts of the hospital or the local prehospital agencies, because it is valuable to have consistency and familiarity. Most devices used in emergency settings are single use and inexpensive.

RGDs all contain two high-volume, low-pressure balloons, one distal to occlude the esophagus and the other proximal to occlude the pharynx, with fenestrations for gas exchange that line up with the laryngeal inlet in between the balloons. RGDs may have a single lumen (King LT) or dual lumens (esophageal tracheal combitube [ETC], EasyTube). Dual lumens provide an option for ventilation in case of insertion into the trachea, but they add complexity for a very rare event. In common practice, RGDs are inserted blindly, but there is a strong literature base supporting direct visualization for placement of the ETC when the equipment and expertise exist. This can be extrapolated to the EasyTube and possibly even the King LT. Such placement technique may mitigate some of the common issues encountered with these devices during insertion, particularly trauma to the posterior pharynx.

The prototypical SGD is the Laryngeal Mask Airway, but there are now a substantial variety of other SGDs available. These devices may be distinguished by an inflatable or gel cuff, if they are available in pediatric sizes, if they include an integral channel to pass a gastric drainage tube (second-generation devices), and if they facilitate blind or endoscopic intubation.

INDICATIONS FOR USE IN EMERGENCY AIRWAY MANAGEMENT

The indications for these devices have expanded over the past several decades and now include potential for use as a:

Primary Airway

- Whenever facemask ventilation is indicated but challenging as long as the patient does not have a gag reflex.
- Cardiac arrest airway management in pediatric and adult patients (see Chapter 5).
- Rapid Sequence Airway, an alternative to RSI for medication-facilitated airway management in the prehospital setting (see Chapter 30).
- As a conduit to facilitate endotracheal intubation (see Chapter 17).

Secondary Airway

- When a patient requires positive-pressure ventilation after unsuccessful intubation attempts or when additional intubation attempts are predicted to be unsuccessful or potentially harmful
- In a failed airway "*can't* intubate, *can't* oxygenate" situation while simultaneously preparing for a surgical airway

CONTRAINDICATIONS FOR USE

There are no absolute contraindications for EGD use during airway emergencies. Reluctance to attempt EGD placement when relative contraindications are present is a common pitfall.

Relative contraindications for EGD use:

Requirement for high airway pressures (obstructive lung disease, obesity, etc.)
High risk for aspiration (blood or emesis in the mouth)
Distal swelling, obstruction, or airway distortion
Intact gag reflex

RGD-specific relative contraindications:

Potential esophageal disease such as strictures, varices, or caustic ingestions (risk of mucosal perforation)

RETROGLOTTIC DEVICES

The esophageal obturator airway and the esophageal gastric tube airway were among the first RGDs developed and paved the way for modern EGDs but do not have a role in contemporary airway management. Current RGDs represent a dramatic improvement over these early devices and have demonstrated efficacy and safety in rapidly establishing oxygenation and ventilation in a variety of emergency situations. The prototypic RGD is the Esophageal Tracheal Combitube (ETC, Tyco-Healthcare-Kendall-Sheridan, Mansfield, MA) although this has largely been supplanted by the King Laryngeal Tube (King LT, Ambu Inc. USA, Columbia, MD). With the ETC and EasyTube, there are separate ports to inflate each balloon, whereas the King LT has a single inflation port that inflates both the upper and the lower balloons with a single bolus of air. The advantage of the latter is simplicity, but during exchange of the RGD to endotracheal tube (ETT), it may be beneficial to be able to maintain esophageal occlusion while deflating the upper balloon for laryngoscopy.

Esophageal Tracheal Combitube

The ETC (**Fig. 13.1**) has been in clinical use longer than any of the other RGDs and has therefore accumulated a large body of evidence describing its indications, contraindications, benefits, and risks. The ETC has been shown to be an easy and effective primary airway, particularly in the prehospital setting, and rescue airway in the event of a failed intubation. Complications are rare but occasionally very serious and likely underreported. These complications are mostly related to upper airway and esophageal trauma from overly aggressive insertion without proper technique or balloon overinflation. The ETC is supplied in two sizes: 37 French (F) catheter SA (small adult) and 41 F catheter Regular, which, according to the package insert, are to be used for patients 4 ft (1.22 m) to 5 ft 6 in (1.67 m) tall and more than 5 ft 6 in tall, respectively. However,

postmarketing research has demonstrated that the small adult size should be used all the way up to 6 ft tall. There is no ETC suitable for use in children or patients <4 ft tall. Owing to its large robust balloons, the ETC can generate some of the highest peak ventilation pressures before leak occurs (up to 40 cm H_2O) and may be the EGD of choice when ventilation is predicted to be challenging. Although the ETC has merits, it has fallen out of widespread use because it cannot facilitate intubation, does not come in pediatric sizes, and has a more complicated insertion technique than other RGDs.

Figure 13.1: Retroglottic devices (RGDs). The most common RGDs: (from left to right): Combitube, King LT-D (first-generation EGD), King LTS-D (second-generation EGD). EGD, extraglottic device.

Rusch Easytube

The Rusch EasyTube is another dual-balloon and dual-lumen RGD that aims to improve on the ETC. If placed in the trachea, the size and shape of the distal tip are similar to a standard ETT. It is suggested by the manufacturer that the risk of tracheal trauma relative to the ETC is reduced because of the smaller diameter of the EasyTube device at the distal tip, although this has not been validated in clinical trials. The EasyTube is latex free and supplied in two sizes, 28 F and 41 F, with the lower end for patients down to 3 ft tall compared to the 4 ft limitation for the ETC. There is minimal evidence from human studies to demonstrate the relative success rate of the EasyTube versus the LMA, ETC, or King LT, although initial data appear promising. Multiple manikin studies show that it is similar to an ETC in speed of insertion, successful ventilations, and skill retention. More data are needed to determine its role in emergency airway management.

The Laryngeal Tube Airway

The laryngeal tube airway (known as King Airway or King LT in North America) (Fig. 13.1) is a latex-free silicone single-lumen RGD that is built on the presumption that blind insertion will virtually always result in esophageal placement. The two balloons are inflated simultaneously via a single port. The disposable versions come with the designator “D,” and those with an open distal tip to permit gastric decompression come with the “S” designator for suction or sump. The most common version for emergency use is the King LTS-D. Approximate interdental distance of 20 mm is required for insertion, comparable to the ETC. Sizing of the King LT is primarily height based, like the ETC, although there are also weight-based sizing guidelines provided for children. A full size range from newborn (<5 kg) to adult is available.

A new iLT-D version to facilitate intubation with a standard ETT and gastric decompression port recently became available in parts of the world and should be available soon in the United States. Although intubation via this device can be performed blindly, it is best facilitated using endoscopic visualization to improve success. Following successful passage of the ETT through the iLT-D, the iLT-D can be removed by disconnecting the bag connector from the ETT, deflating the cuff on the iLT-D, and then removing

it over the ETT while stabilizing the ETT. There is not sufficient data available yet to evaluate this product, but it may show promise for challenging airways such as the morbidly obese.

Ease of use has made the King LT one of the most common RGDs used in prehospital care. It is inserted through the pharynx and blindly into the esophagus in a similar fashion as the ETC, but there is less reported experience using a laryngoscope, and the Lipp maneuver (manually bending the tip to help navigate the base of the tongue) is not recommended. There have been rare, published reports of unanticipated tracheal placements with this technique.

Insertion Technique—Assuming No Visualization

1. Chose the correct size device based on patient weight (pediatrics) or height (adults)
2. Assemble supplies
3. Test cuff and then deflate
4. Apply lubricant if mucous membranes not very moist
5. Place patient in neutral or sniffing position
6. Perform a jaw lift with the nondominant hand
7. Place the LT into the mouth at an approximately 45° angle to midline
8. Advance the tube into the pharynx while rotating to midline
9. Gently and smoothly advance until the color-coded bag connector flange is aligned with the incisors unless resistance is encountered.
10. The balloons should be inflated through the single port with the recommended amount of air for that size device. A size 4 King-LT (the most used size) requires 60 mL of air.
11. Ventilation is then attempted *while* the device is slowly withdrawn, monitoring carefully until unrestricted ventilation and chest rise is noted along with capnography and equal lung sounds. It is common for providers to stop withdrawal when the very first sign of ventilation is noted, which may leave the distal ventilation outlets too deep such that they may be delivering air to the stomach and not the lungs. We suggest withdrawing about 1 or 2 cm (less for smaller pediatric sizes and more for large adult sizes) *past* the point when ventilation first

occurs and halting when ventilation becomes most prominent and easy to accomplish. This ensures all ventilation is directed to the lungs.

12. Continue appropriate ventilation
13. Secure the device in position
14. Pass a gastric tube if possible to decompress the stomach

If a properly sized device is unable to ventilate, it is typically overinserted. Once correctly positioned, the King LT works in a fashion that is very similar to that of the ETC, with similar ventilation and oxygenation capabilities and aspiration protection. Although there have not been extensive reports of complications, airway trauma has been reported. Clinically significant tongue swelling has also been reported, in one case occurring as early as 45 minutes post insertion, but such cases seem rare. The balloon may also displace the tongue anteriorly, creating the illusion of edema. Still, prolonged insertion of any RGD is not recommended, and exchange for an ETT is encouraged within 4 hours when it can be done safely. Because of concerns about mucosal ischemia and possible effects on the cerebral perfusion, it is advisable to use a manometer to check balloon pressures instead of relying on suggested volumes.

SUPRAGLOTTIC DEVICES

SGDs consist of a laryngeal mask (cuff) that seats over the glottis, making a seal at the proximal esophagus, base of tongue, and lateral glottic structures, and a ventilation tube that traverses the pharynx and exits the mouth, terminating at a bag connector. There are many brands and varieties of SGDs from which to choose. The major functional differences include (a) the presence or absence of a gastric tube channel; (b) whether the cuff is inflatable, noninflatable, or self-pressurizing; (c) the ability to use as an intubation conduit; (d) ease of insertion; and (e) the available size range. Historically, SGDs were designed and intended specifically for elective airway management in the surgical suite, but there is now widespread use in emergency settings, prompting new designs incorporating these preferred features.

SGDs are easy to use, highly successful, produce little in the way of adverse hemodynamic responses on insertion, and play a significant role in

rescue emergency airway management. Ventilation success rates near 100% have been reported in operating room series and around 95% in emergency series. Blind intubation has been shown to have consistently high success only with the LMA Fastrach, but endoscopic intubation is now feasible through many SGDs for providers in most settings with a minimum of training (see Chapter 17). Like any EGD, the SGDs do not constitute *definitive airway management*, defined as a cuffed ETT in the trachea, but they do provide substantial aspiration protection.

Laryngeal Mask Airways

The Laryngeal Mask Company (owned by Teleflex) developed the original and prototypic SGD in 1981, now called the LMA Classic (**Fig. 13.2**). The company currently offers several other versions of the LMA, including three that are specifically intended for emergency use: the LMA Supreme, the LMA Protector, and the LMA Fastrach, which is also known as the intubating LMA. Although their other SGDs may work as rescue devices, we do not recommend the LMA Classic, LMA Unique, LMA Unique EVO, LMA Flexible, or LMA ProSeal (**Fig. 13.3**) for settings that deal predominantly with airway emergencies.

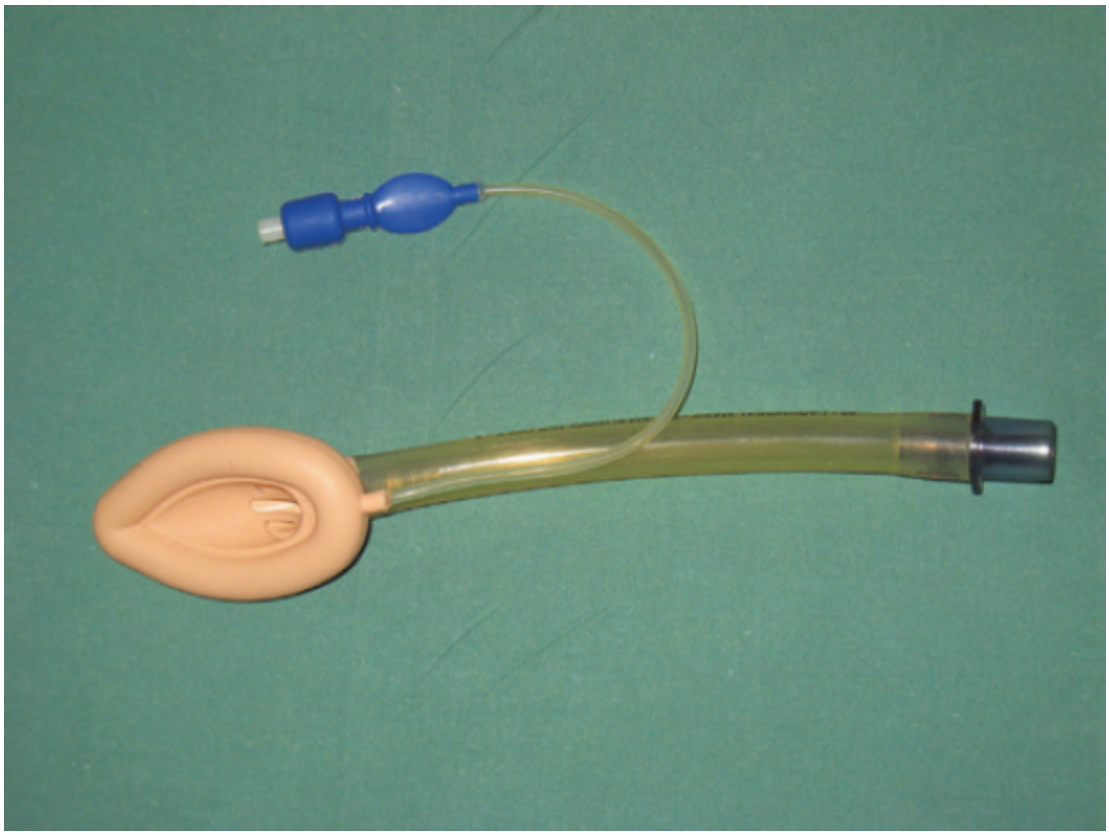

Figure 13.2: LMA Classic. Note the aperture bars at the end of the plastic tube intended to limit the ability of the epiglottis to herniate into this opening.

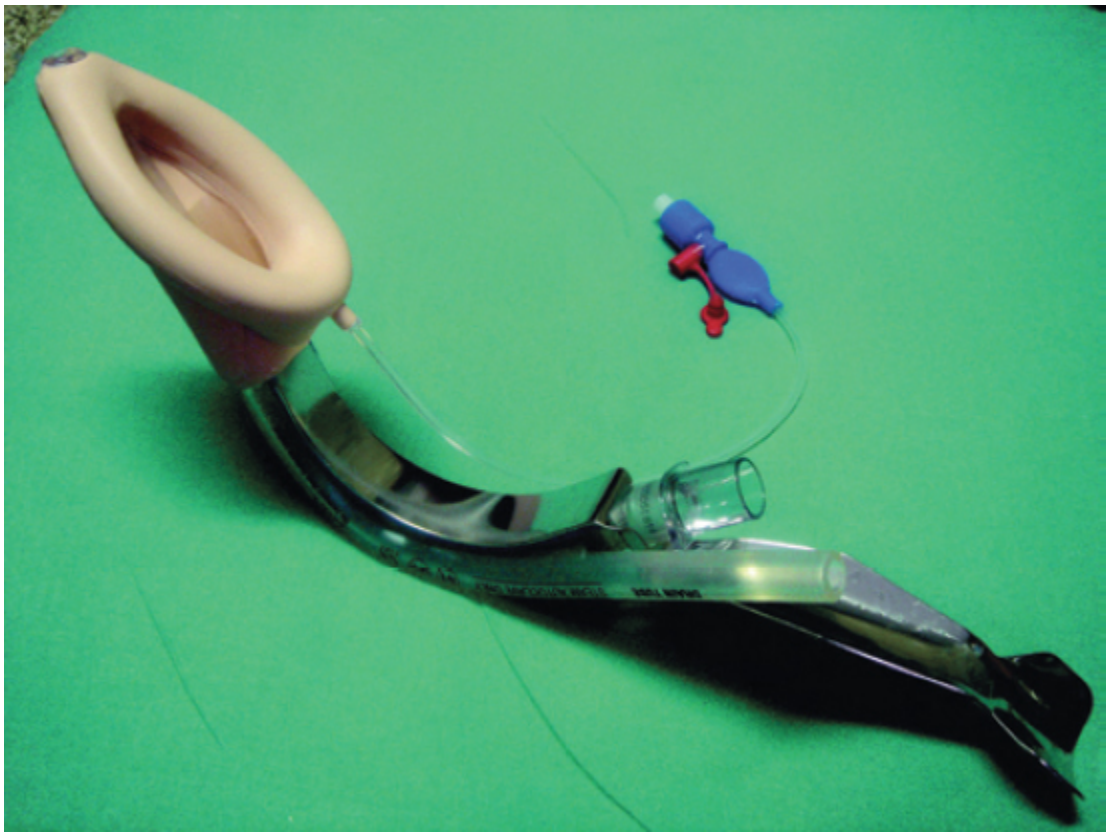

Figure 13.3: LMA ProSeal. Note the drain tube and distal orifice to permit gastric tube passage and drainage.

The LMA Supreme has compelling design characteristics that make it a good device for emergency airway management (**Fig. 13.4**). It is easy to insert, has higher leak pressures than earlier LMA iterations, has a built-in bite block, and contains a channel through which a gastric tube can be passed. It has a good track record of clinical experience and research support and is also available in a broad range of sizes. The major limitation with the LMA Supreme is the inability to use it as a conduit for subsequent intubation.

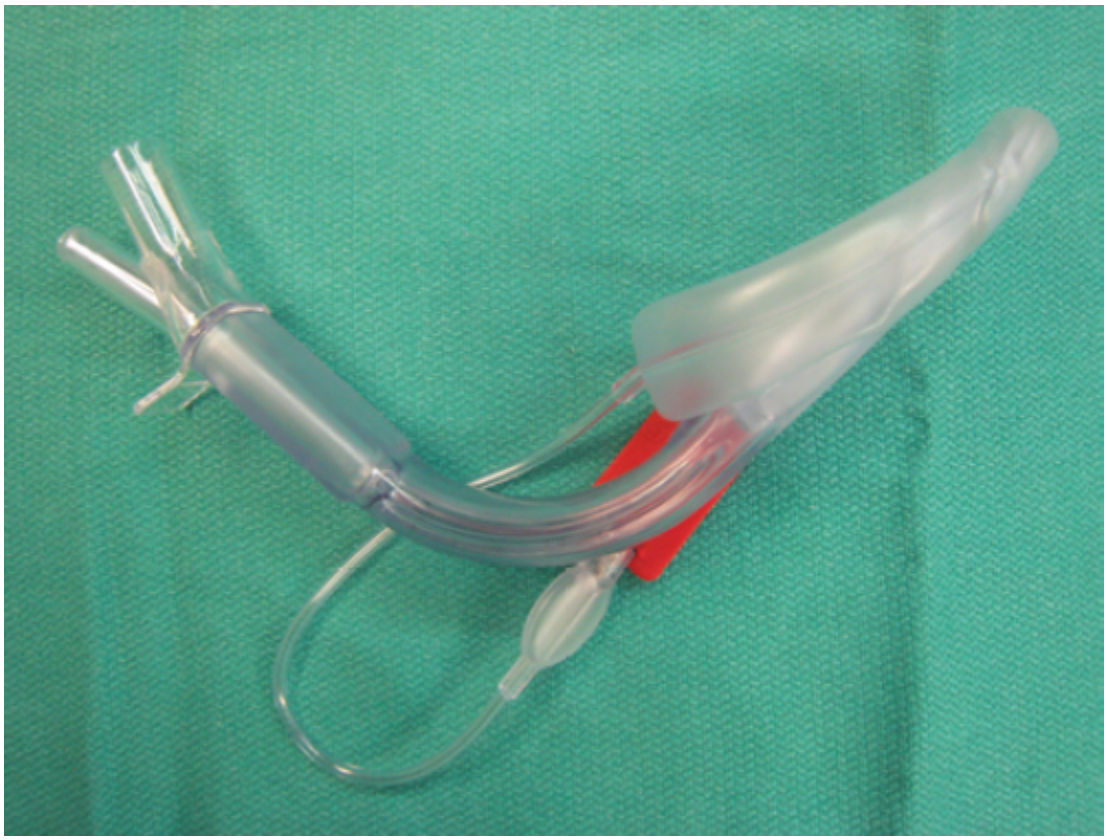

Figure 13.4: LMA Supreme. The rigid construction of the tube and the curvature of the device enhance insertion characteristics and the immediacy of the seal obtained once inflated.

The LMA Protector (**Fig. 13.5**) is a newer silicone single-use device that is available with both a gastric drainage tube port and a pilot balloon that incorporates Cuff Pilot technology, a pilot balloon pressure indicator. Initial studies show the Protector has an even better seal pressure than the LMA Supreme and serves as a conduit for endoscopically guided intubation but is so far only available to fit larger children and adults.

Figure 13.5: Supraglottic devices. Five of the common intubating second-generation laryngeal mask extraglottic device: (from left to right) Intersurgical i-gel, Cookgas air-Q Blocker, Cookgas air-Q3SP (self-pressurizing cuff), Ambu AuraGain, LMA Protector.

The LMA Fastrach, also called the intubating laryngeal mask airway (ILMA), combines the high insertion and ventilation success rates of the other LMAs with special design features to facilitate blind intubation in the most cases regardless of obesity, spinal precautions, and secretions (**Fig. 13.6**). It is available in both reusable and single-use forms but only for older children and adults and without the benefit of a gastric decompression channel. Despite these limitations, we believe the LMA Fastrach is an underutilized device in emergency airway management because of its unique design allowing blind intubation.

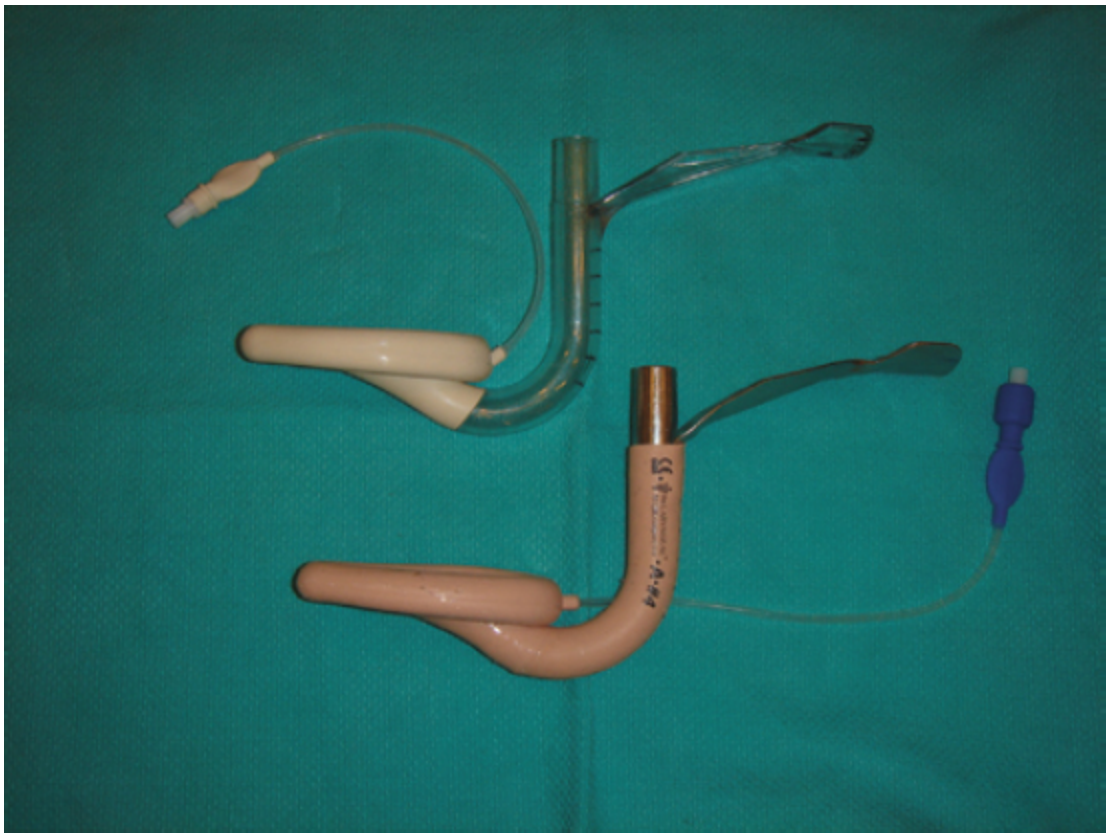

Figure 13.6: LMA Fastrach or ILMA. Both the reusable (bottom) and disposable variants are pictured. The most unique feature of this device that confers a particular advantage is the handle to permit positioning in the hypopharynx to improve airway seal and the capacity for adequate gas exchange. This factor may be crucial in rescuing a failed airway.

Ambu LMA

The Ambu LMA family of devices include the AuraOnce, Aura40, AuraStraight, Aura-i, AuraFlex, and AuraGain (**Figs.** 13.5 and **13.7A** and **B**). Of these devices, the AuraGain is the best for emergency airway management because it has a gastric tube channel and comes in a full range of sizes; furthermore, studies have demonstrated excellent seal pressures and endoscopic intubation conditions. Although there are limited published data on the AuraGain in emergency airway management, there is extensive positive experience with it in prehospital settings.

A

#5

Figure 13.7: A: Range of sizes of the Ambu AuraOnce LMA. B: Ambu Aura-i LMA.

Cookgas Air-Q

The Cookgas air-Q (formerly known in the reusable version as Cookgas ILA) device has several versions, including Reusable, Disposable, Blocker, and the new air-Q3 (Fig. 13.5). Many of their products also have the option of a self-pressurizing ("sp" in Cookgas branding) cuff, which means that with each ventilation delivered, some air is directed into the cuff to give a burst of pressure and create a seal yet allows partial deflation on expiration to relieve mucosal pressure. First-pass success in ventilation is high, they come in a broad range of sizes, and endoscopic intubation is very successful through them. Blind intubation has also been shown to be reasonably successful in adults and pediatrics without the requirement for specialized endotracheal tubes. The air-Q Blocker and air-Q3 are the versions of choice for emergency airways because they are slightly stiffer and therefore easier to insert and have gastric tube channels.

Intersurgical I-GEL

The i-gel (Fig. 13.5) is a disposable, preshaped, noninflatable device made with a soft, gel-like polymer that create an immediate seal without the need for inflation. Shortly after insertion, the warm, moist environment of the patient's hypopharynx allows the gelatinous material to become more pliable and finish filling supraglottic soft-tissue gaps. After this process, the seal becomes even more robust. Peristent device leak has been reported when used in extreme low-temperature outdoor environments. It incorporates an integral bite block and is available in a range of sizes from small infant to large adult. The i-gel is easy to insert without a cuff inflation step, and there is a long track record of international use in emergency and prehospital applications. Endoscopic intubation is highly successful through the i-gel, although blind intubation success has been mixed. The i-gel has a gastric tube channel, but it is relatively small, which is a disadvantage in emergency situations where patients may have a full stomach. Conveniently, the size 4 i-gel accommodates patients from 50 to 90 kg,

which is a far larger range than most adult SGDs and therefore eliminates uncertainty in choosing the proper size. There is also an i-gel O_2 version that includes a port for passive oxygenation during cardiac arrest management. The i-gel O_2 can be purchased in a "Resus Pack," which includes lubricant and a securing device all in one bubble package.

GENERAL TECHNIQUE FOR SGD USE

Select the Appropriate Size Device

SGDs sizing is generally based on ideal body weight, although some manufacturers recommend actual body weight. SGDs intended for emergency use come with clear weight ranges listed on the packaging and the device itself.

Prepare the Device for Insertion

1. Cuff: for devices with an inflatable cuff, traditional manufacturer recommendations have called for complete deflation prior to insertion. Recent experience with the newer devices suggests that insertion without adding or subtracting the air that comes in the device is often more effective and helps prevent the tip from flipping back (**Fig. 13.8**). Air can then be added if necessary, although they tend to seal better with less rather than more air volume. The i-gel and air-Q sp models do not require inflation or deflation.

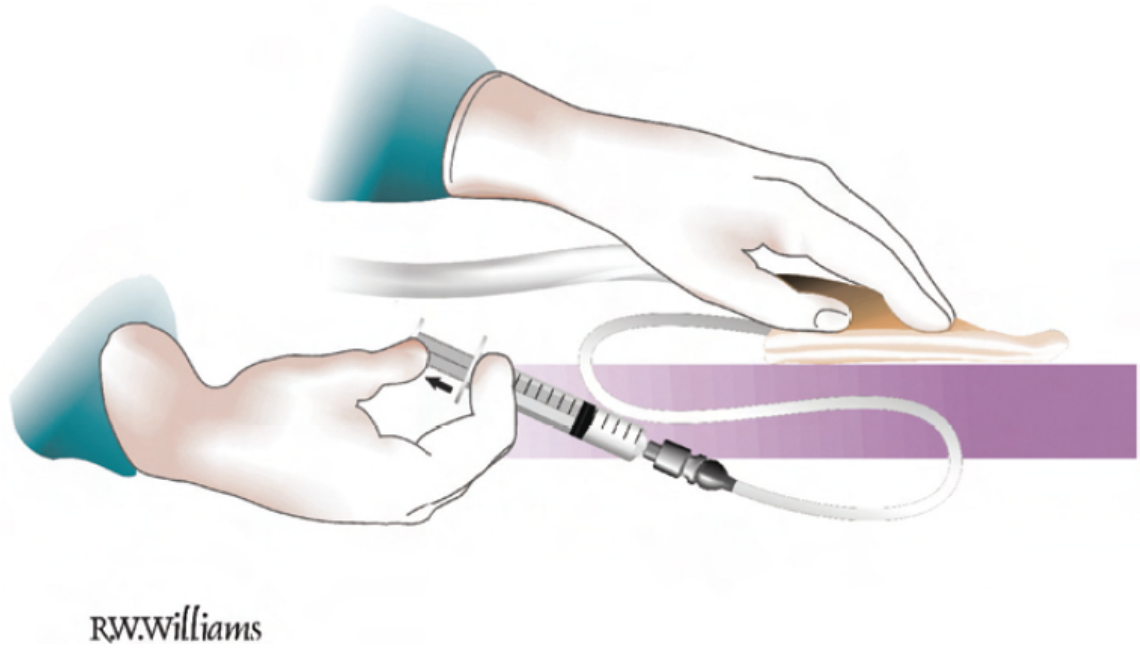

Figure 13.8: Correct method of deflating the LMA Cuff.

2. Lubrication: if the mouth is dry, a water-based lubricant applied to the posterior surface of the cuff and ventilation tube will facilitate rapid atraumatic insertion. Keep lubricant out of the bowl of the cuff.

Prepare the Patient for Insertion

1. Muscle relaxation: in the emergency setting, muscle relaxation and attenuation of gag reflex occurs either because of the clinical condition (ie, cardiac arrest) or from the administration of an induction agent and paralytic. Primary use of medications to facilitate SGD placement is referred to as rapid sequence airway (RSA) and discussed in Chapter 30. More commonly, an induction agent and paralytic have already been administered for rapid sequence intubation (RSI), and the SGD is subsequently placed when intubation attempts have failed and/or oxygen saturations cannot be maintained. In these cases, there is usually sufficient residual muscle relaxation, but in cases of multiple intubation attempts it is possible that additional medication will be required.
2. Positioning: when not contraindicated by concerns for cervical spine injury, placement in the sniffing position or head extension is ideal. A

jaw thrust is usually helpful as well.

Insert the Device

Open the mouth as wide as possible and direct the SGD along the hard palate and advance over the back of the tongue, allowing the natural curvature of the SGD to follow the curvature of the pharynx and hypopharynx until it seats in position (**Figs. 13.9-13.13**). The older, more flexible SGDs often require placement of a finger into the mouth at the cuff-tube junction (Fig. 13.9), although this is typically no longer necessary with the new SGDs with stiffer ventilation tubes.

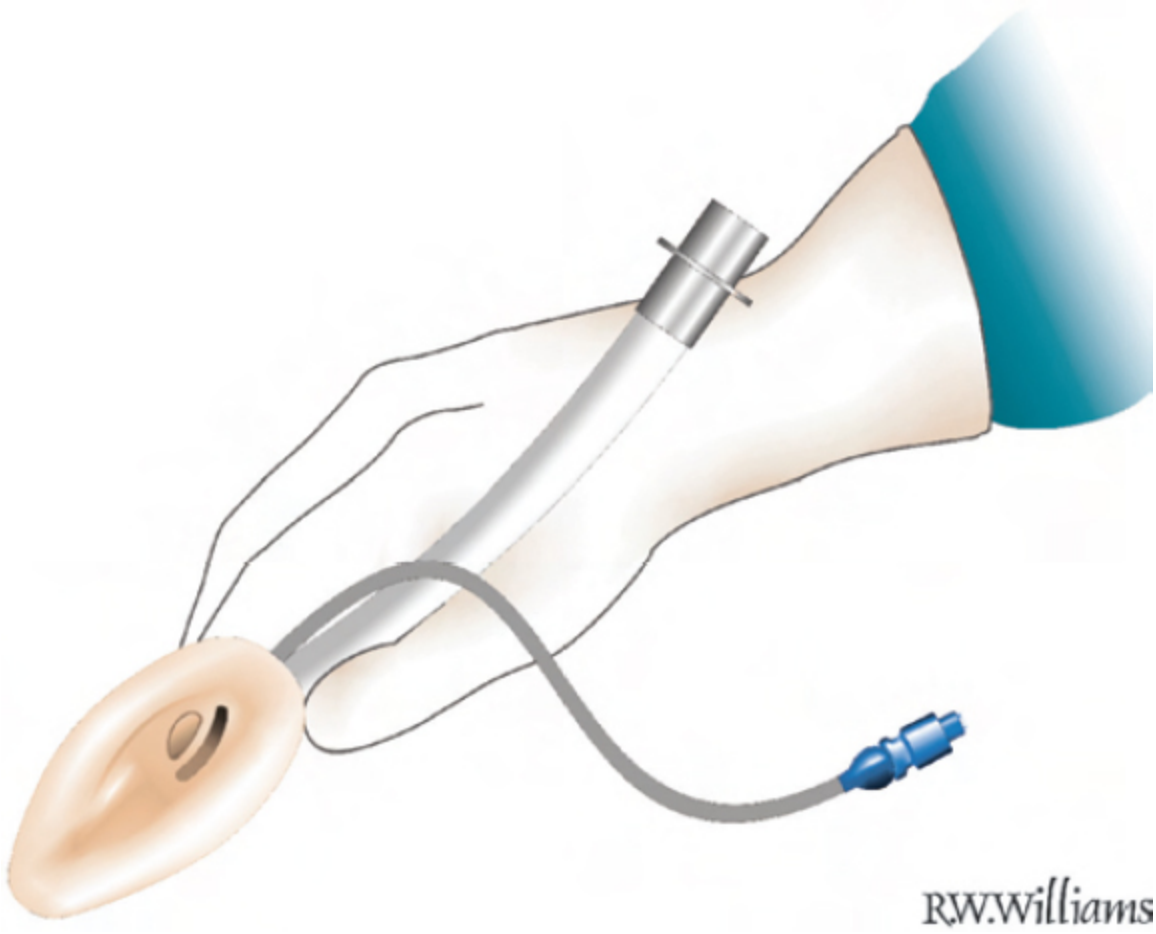

Figure 13.9: Correct position of the fingers for LMA Insertion.

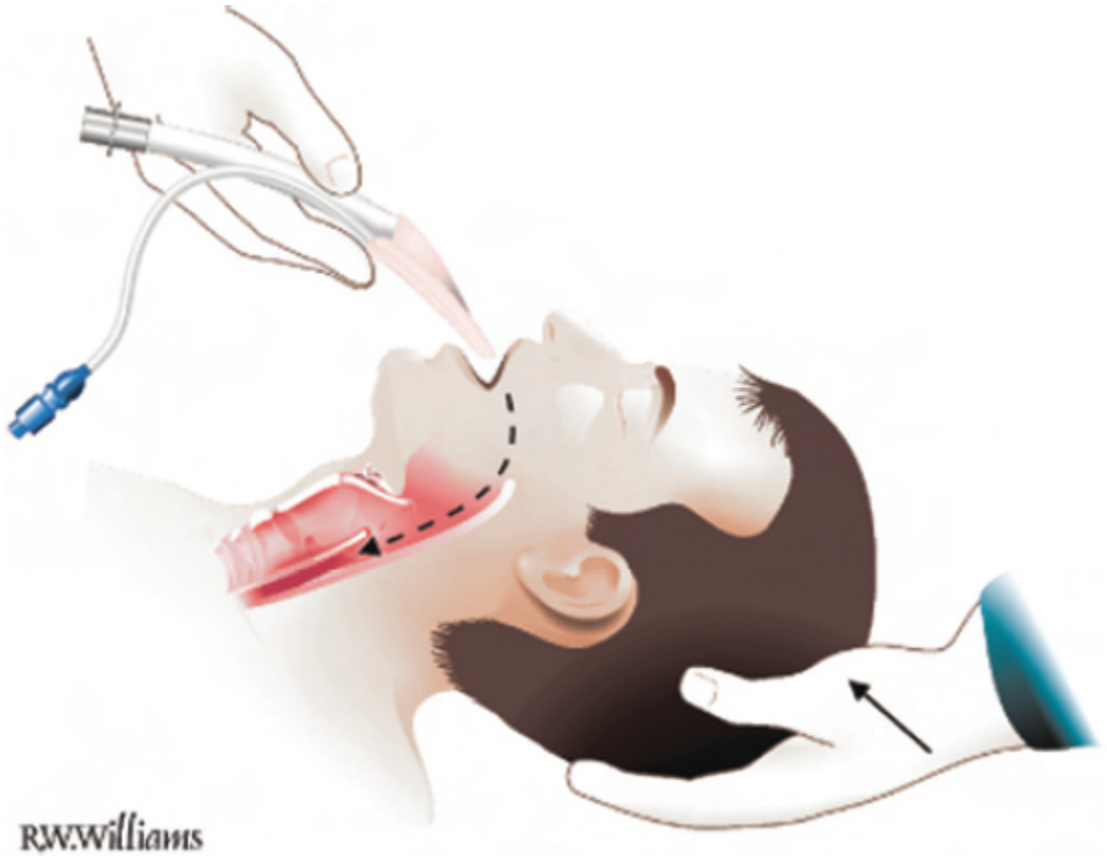

Figure 13.10: Starting insertion position for the LMA Classic and LMA Unique.

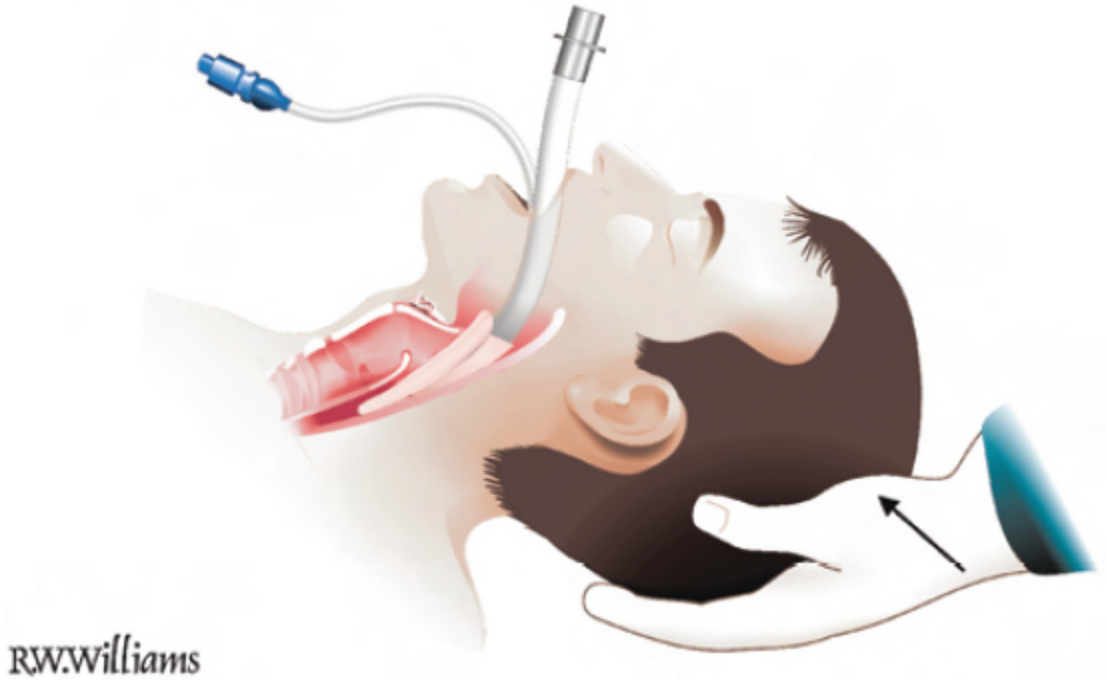

Figure 13.11: Insert the LMA to the limit of your finger length.

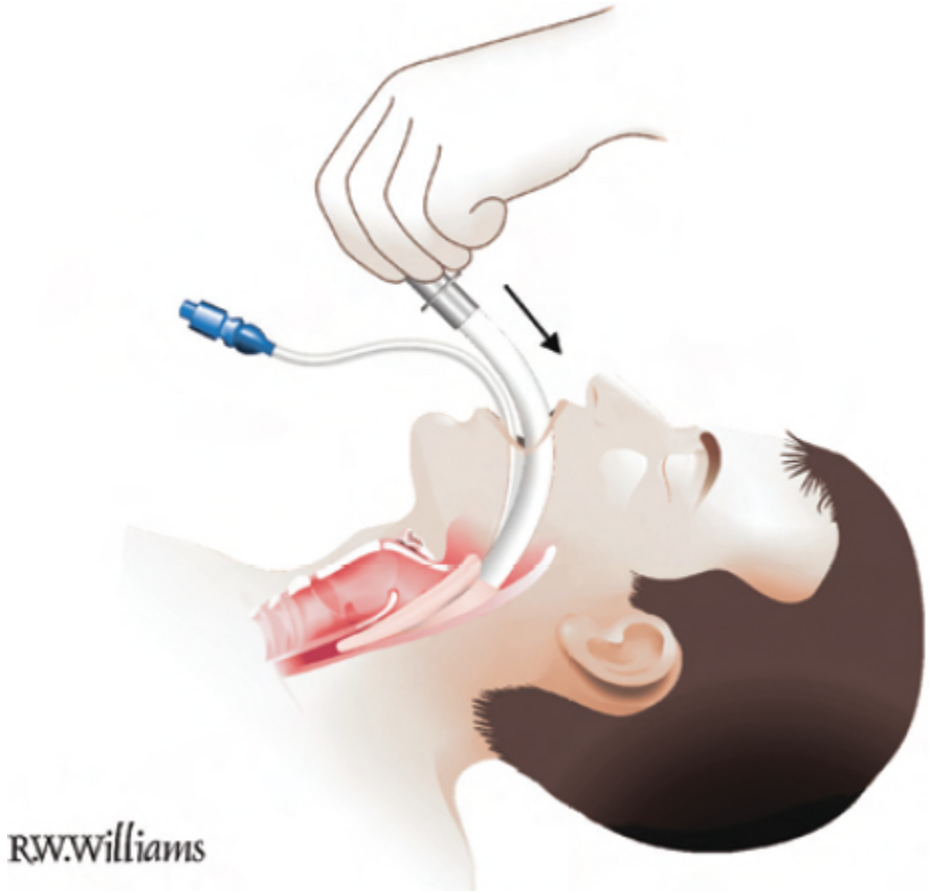

Figure 13.12: Complete the insertion by pushing the LMA in the remainder of the way with your other hand.

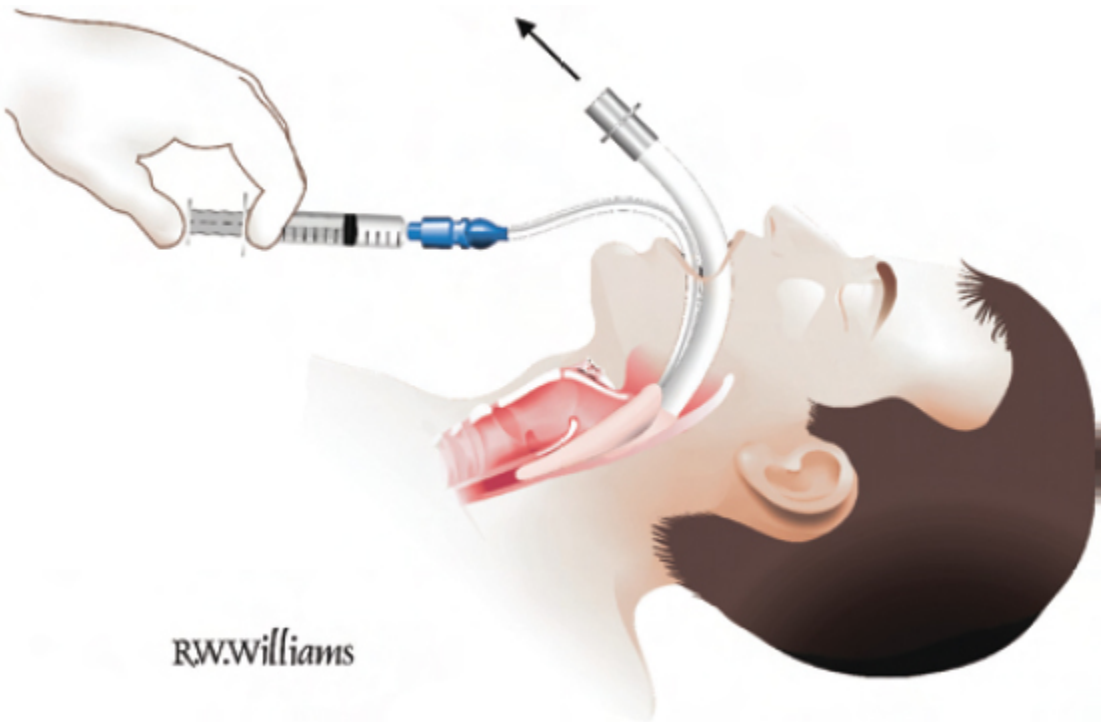

Figure 13.13: Inflate the collar of the LMA.

Postplacement Management

1. Visually assess that the SGD was sized correctly and seated appropriately. Adjust or reinsert alternative size as indicated.
2. Assess ventilations using waveform capnography, looking at chest rise, and listening/feeling for air leaks at the mouth.
3. If ventilation is completely obstructed, the primary concern is that the tip of the cuff has flipped over or the epiglottis was flexed down toward the feet. Withdraw the SGD several centimeters with the cuff inflated, reinsert to the correct depth, and reevaluate.
4. If there is an air leak present and an inflatable cuff, add small volumes of air, keeping track of the maximum cuff volumes, which are usually indicated clearly on the SGD sidewall. Keep in mind that overinflation can also result in an air leak.
5. Once you are confident that the SGD is functioning properly, it can be secured and ventilation continued via a ventilator.

COMPLICATIONS AND LIMITATIONS

Unfortunately, the distal tip of the cuff can roll backward on insertion, hindering optimal placement and cuff seal. This process also likely contributes to pharyngeal abrasions and bleeding that sometimes occurs on insertion. Some authorities recommend partial inflation of the cuff to minimize tip roll, although there is little evidence that this helps; others suggest the up/down maneuver (see earlier discussion). Insertion of the LMA Classic and LMA Unique "upside down," and rotating into place once in the hypopharynx, has also been described and is preferred by some. Our preferred method is a standard insertion, as described earlier.

Achieving a seal sufficient to enable positive-pressure ventilation with an SGD may be difficult. Keeping the tube portion of the device in the midline and altering the position of the head and neck from flexion (more usual) to neutral or extension may be of help. Overall, ventilation success rates are very high with all SGDs. Optimal positioning improves ventilatory effectiveness and, in the case of the LMA Fastrach, facilitates intubation. It is not known to what extent SGDs protect the airway against the aspiration of gastric contents in emergency airway patients, so the device is considered a temporizing measure only.

SUMMARY

With many EGDs available and more designs and redesigns coming on the market, this is a rapidly evolving area of emergency airway management. In emergency situations, EGDs may serve as highly effective primary and rescue airways. The ideal EGD would be inexpensive, easy to use, available in pediatric sizes, have a high first-attempt success for oxygenation and ventilation in a wide variety of clinical circumstances, allow gastric drainage, and serve as a conduit to the trachea for intubation. A number of devices now fulfill these requirements. It is important for clinicians to understand the distinctions between retroglottic and SGDs and the nuances of individual products they may encounter.

EVIDENCE

Is the King LT airway useful as an EGD?

Simple handling, possible aspiration protection, potential for intubation with forthcoming designs, and availability in newborn to adult sizes are

considered to be advantages of the King LT.[1-4] There is evidence that this device is easily learned by EMS personnel and provides more effective ventilation than bag-mask devices.[5-7] The evidence that the King LT is useful as a rescue airway or in patients where intubation has failed is limited and, for the most part, is based on case reports.[5,8,9] However, a recent publication provides compelling evidence that this device may be of use in the difficult and failed airway.[10]

Are there potential problems that I ought to be aware of with the King LT?

As with the ETC, the inflated balloons may lead to mucosal ischemic injury. The risk is higher when left in place for prolonged periods (>4 hours) or when the balloons are overinflated.[4,11]

Are SGDs effective in emergency, difficult, and failed airway management?

There is ample evidence that SGDs are useful in emergency airway management, both for the management of the difficult airway and for rescue of the failed airway.[12-16] SGDs that optimize first-pass success, high seal pressure, and an ability to permit intubation are generally preferred. Furthermore, numerous studies have demonstrated that SGDs are at least as effective as other methods of airway management for patients requiring cardiopulmonary resuscitation (CPR).[17-19]

How easy is it for nonexperts to successfully use SGDs?

A variety of authors have described successful insertion and use of both classic and newer devices by minimally trained rescuer nonmedical personnel, prehospital care providers, nurses, and respiratory therapists and inexperienced airway managers.[20,21] Some of the EMS literature has questioned the ease of use of the device as a primary method of airway management in emergency medical services (EMS),[22] although analysis has shown that training is key to its successful use.[23]

How do the preformed cuffless devices compare to more traditional cuffed SGDs?

The i-gel has compared favorably in most respects to other SGDs. Compared to the LMA Classic/Unique, physiologic response to insertion is equivalent or improved, and there is less gastric insufflation and increased

leak pressures in both children and adults.[13,24,25] Evidence is mixed but generally good regarding ease of insertion and first-pass ventilation success. The i-gel seal adequacy has been found to be equivalent to most SGDs.[26,27] Intubation through the i-gel has moderate success blindly but, essentially, 100% success with an endoscope.[28-30]

What success rates have been achieved intubating through the intubating SGDs?

Blind intubation success rates are inconsistent and range from 40% to 99%, except for the LMA Fastrach, which consistently demonstrates >90% success.[13,22,28,30-35] Techniques that utilize the EGD as a conduit to the trachea and use an endoscope for visualized intubation have success rates routinely over 90%.[22,29,31,33,35-39]

Is it safe and effective to pass a bougie through an EGD to facilitate intubation

Passage of a bougie through a King LT to facilitate intubation was not successful in a cadaver model and may result in complications.[40] However, in certain SGDs, use of a bougie did assist in successful tracheal intubation,[41,42] although extreme care must be taken to avoid mucosal trauma, avulsion of an arytenoid or vocal cord, and tracheal perforations.

What complications with short-term use of SGDs might I expect?

The incidence of difficult ventilation or major airway adverse events with SGDs is quite low and is thought to be significantly less than standard tracheal intubation or bag-mask ventilation.[43] The SGD may fail to provide a seal sufficient to permit adequate ventilation, often attributed to the sensitivity of the seal to head and neck position.[44,45] Insufflation of the stomach may occur. Although SGDs may not offer total protection from the aspiration of regurgitated gastric contents, they protect the aspiration of material produced above the device with varying degrees of success.[46] Cricoid pressure may or may not interfere with proper functioning of an SGD, although in practice each case is evaluated individually.[47] Negative-pressure pulmonary edema, caused by a patient sucking hard to inspire against an obstruction, followed by translocation of fluid into the alveolar spaces, has been reported with patients biting down on an SGD and can be

prevented by using an SGD with an integral bite block or placing folded gauze flats between the molar teeth on either side.[48]

Are EGDs effective in the pediatric population?

There is ample evidence that SGDs are appropriate and widely accepted as rescue devices in children.[49,50] Some authors have described guidelines for selecting the appropriate size in children, and the manufacturer provides a pocket card to guide clinicians. There is also evidence to support the use of SGDs in both routine and difficult pediatric airway management.[51-54] Manikin studies suggest that the pediatric King LT can be placed more rapidly and with a greater degree of success compared to endotracheal intubation by prehospital providers.[55,56] The very low rate of advanced airway management in pediatric patients in the prehospital setting limits meaningful data on pediatric use.[57]

Do EGDs provide any aspiration protection?

EGDs appear to provide much more aspiration protection than originally thought. In a cadaver model, seal pressure of seven different extraglottic devices were variable but very substantial.[44] In a small study of EMS patients specifically looking at aspiration, rates with EGDs are not statistically higher than with endotracheal intubation.[58] In two very large studies of cardiac arrest that compared intubation with a King LT or i-gel, aspiration rates were not statistically different.[59,60] In both prehospital and ED case series looking at use of RSA, aspiration rates were quite low.[61,62] A study of hospitalized trauma patients found that prehospital airway strategy did not impact rates of ventilator-associated pneumonia.[63,64]

Should cardiac arrest patients be managed primarily with an EGD?

EGDs are easily inserted and minimize interruptions during CPR with less training requirements, making them an attractive management strategy during cardiac arrest. Patient outcomes between extraglottic airways and endotracheal intubation have now been compared in two large prospective, randomized prehospital trials. One, in the United States, found improved survival and neurologic outcomes with the King LT compared to intubation.[60] The other, in the United Kingdom, found equivalent outcomes between i-gel and intubation.[59] Many EMS systems and some hospital-

based providers have taken these data to support an EGD-based initial airway strategy for cardiac arrest.

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CHAPTER 14

Managing the Patient With an Extraglottic Device in Place

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INTRODUCTION

Extraglottic devices (EGDs) are primary devices for airway management during cardiac arrest or the failed intubation in any setting. Providers must be comfortable assessing and managing a patient once an EGD is in place. Whether the EGD was used as a primary airway without prior attempts at intubation or secondarily in the event of a failed airway can have important clinical implications. Because EGDs will often be replaced with an endotracheal tube (ETT) for definitive airway management, providers should be able to match the appropriate exchange technique to the device that is in place and the clinical scenario encountered.

Emergency medical services (EMS) agencies typically carry only one EGD model. Hospital-based providers should become familiar with devices used within their institution and by EMS agencies in their catchment area; this should include hands-on practice and scenario-based simulation whenever possible. Intensive care units (ICUs), emergency departments (EDs), and critical care transport agencies should consider keeping samples of common devices on hand for rapid reference. In-depth knowledge of the various EGDs you are most likely to encounter will improve patient care and facilitate further management.

MANAGING A PATIENT WITH AN EGD IN PLACE

Although EGDs are not definitive airways (ie, cuffed tubes within the tracheal lumen), they are reliable conduits for oxygenation and ventilation and offer variable degrees of aspiration protection. Therefore, the provider's initial thought process should focus on confirming and optimizing gas exchange rather than on immediate exchange for an ETT. Most critically ill or injured patients with an EGD in situ have other competing priorities. If further airway interventions can be deferred safely for even a few minutes, it will often allow the provider to address these other issues and create a more controlled situation for further airway management.

ASSESSMENT

Rapid assessment of gas exchange should be the first step. Visually assess whether the device appears to be sized correctly and seated in an appropriate position and whether the pilot balloon pressures seem appropriate (if present). Confirm that no significant air leak is present. Confirm gas exchange as one would do for an ETT. Clinical observations such as breath sounds, chest rise, and gastric distention are important, but waveform capnography is paramount. Any correctable issues should be rapidly addressed, such as repositioning the device or adding/removing air from inflatable cuffs.

TROUBLESHOOTING OXYGENATION

If ventilation is adequate but oxygenation is poor despite an F_{IO_2} of 100%, hypoxemia is more likely on account of patient pathology than device failure (**Fig. 14.1**). In that case, assessing for and treating a pneumothorax if present should be performed. Other common etiologies depend on the clinical scenario but often involve air space disease and shunt physiology that may respond to an increase in mean airway pressure, usually by increasing positive end expiratory pressure (PEEP), if not contraindicated. We commonly employ PEEP levels of 10 cm H_2O with an EGD and have reported levels as high as 17 cm H_2O with a Laryngeal Tube.[1] Adding sedation, analgesia, and neuromuscular blockade to treat ventilator dyssynchrony. If such maneuvers are successful, semielective exchange can be considered as discussed further on.

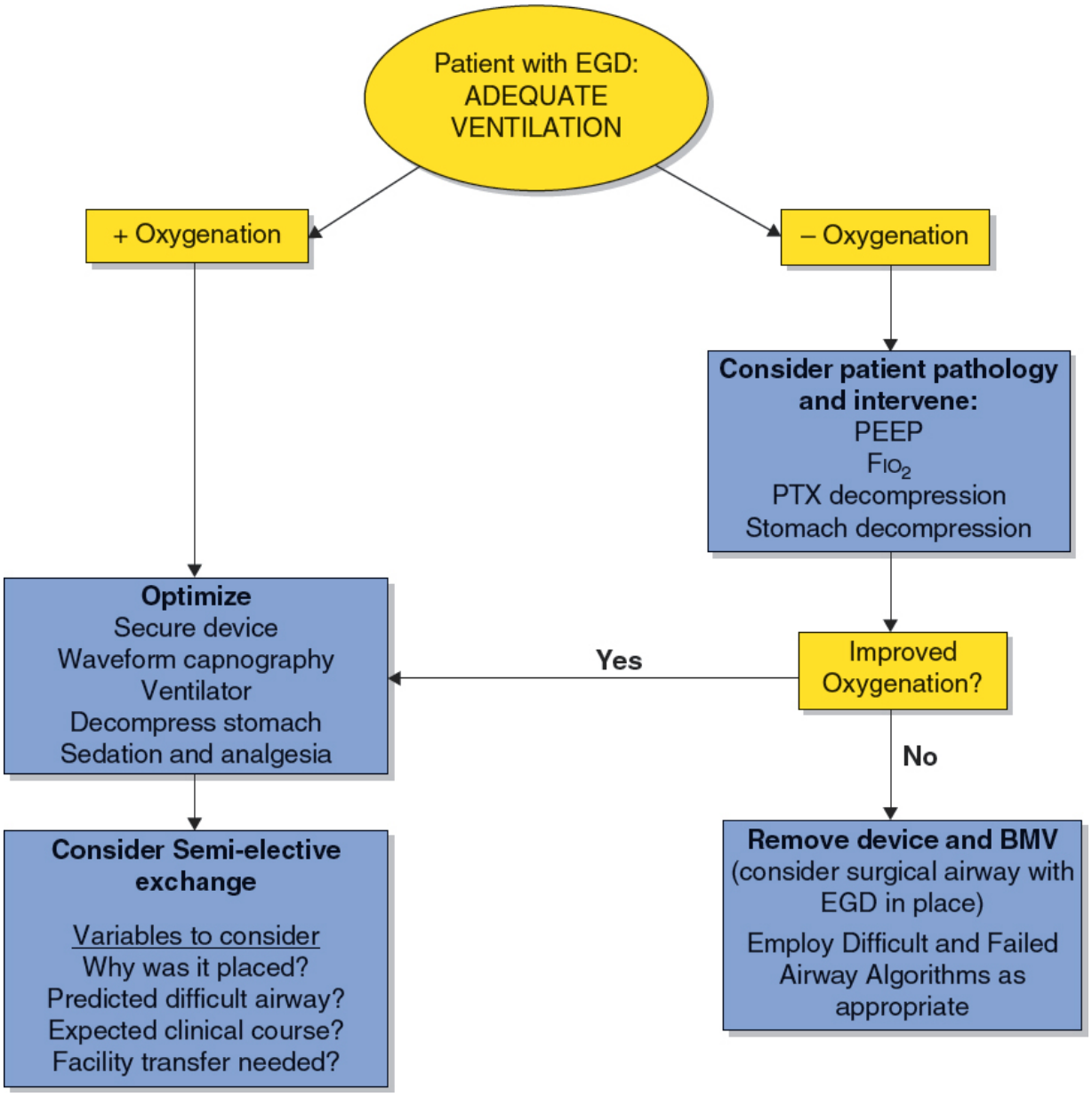

Figure 14.1: Algorithm for assessment and troubleshooting of an EGD when ventilation is adequate. EGD, extraglottic devices. PEEP, positive end-expiratory pressure; PTX, pneumothorax.

If such maneuvers are unsuccessful, then the provider should err on the side of rapid exchange to ensure that the device was not contributing to oxygenation failure. A common option for this type of exchange is rapid sequence intubation (RSI) with a “double setup” for surgical airway. After ensuring the patient has received appropriate analgesia, sedation, and neuromuscular blocking medication, the EGD can be removed and one best

attempt at laryngoscopy made before moving to a cricothyrotomy because EGD rescue is now assumed to be unreliable. If enough hands are available, continued oxygenation efforts with bag-mask ventilation (BMV) may offer additional time for cricothyrotomy. Another option in this situation—especially if intubation is predicted to be quite difficult—is to leave the EGD in place, continue whatever degree of oxygenation and ventilation is occurring and perform a surgical airway.

TROUBLESHOOTING VENTILATION

As noted in **Figure 14.2**, air leak and bag compliance guide further actions. Specifically, *failure to ventilate accompanied by high resistance/pressure* strongly suggests either an occlusion of the circuit or EGD or patient pathology such as bronchospasm or laryngospasm, mucus plugging, foreign body obstruction, tension pneumothorax, tracheal stenosis, or excessive auto-peep. In contrast, *failure to ventilate accompanied by low resistance/pressure* points to a poor interface between the EGD and the patient's airway or, rarely, disruption of the airway distal to the seating of the device. Troubleshooting should be directed at the identified problem(s).

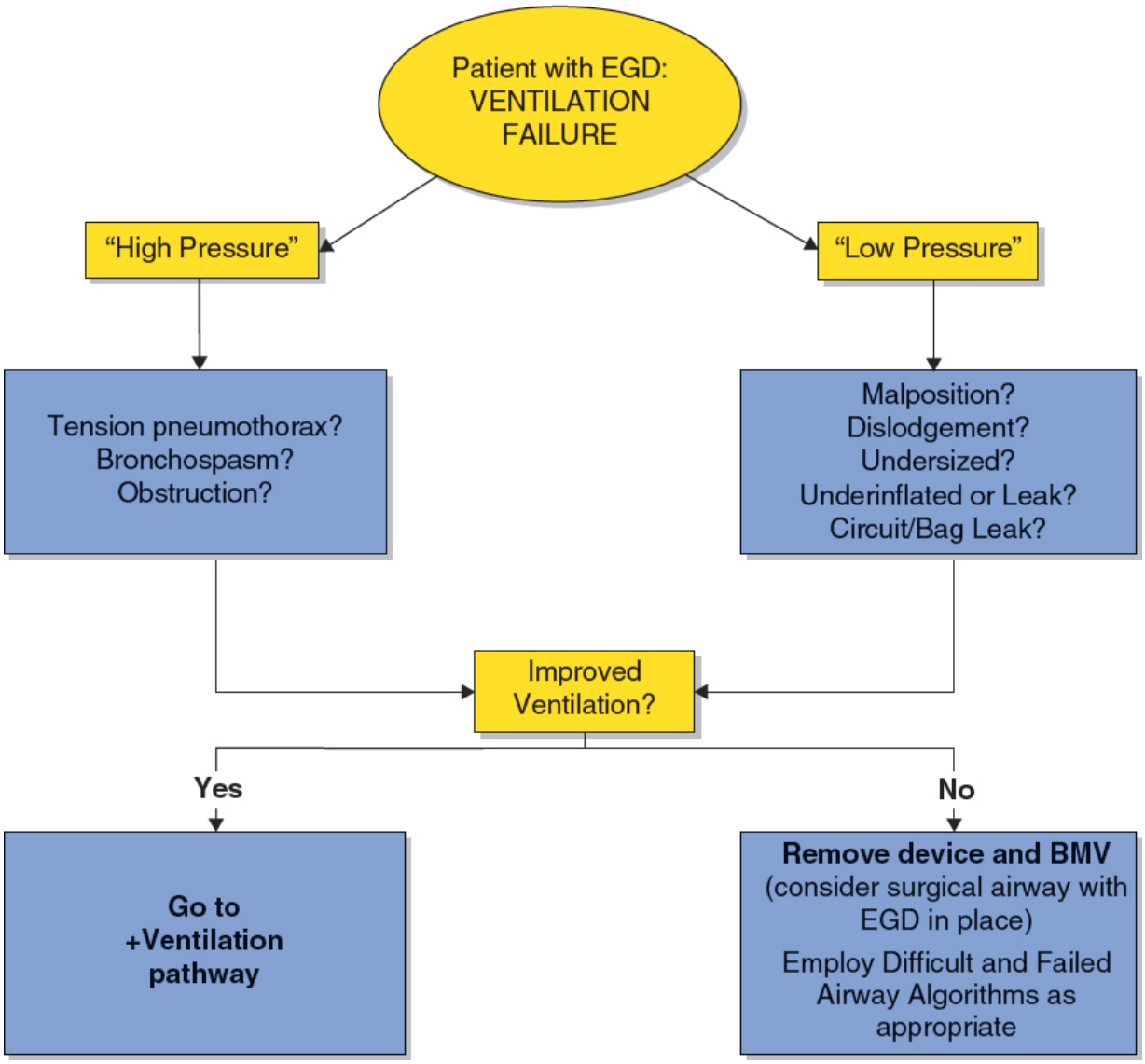

Figure 14.2: Algorithm for assessment and troubleshooting of an EGD when ventilation is not adequate. EGD, extraglottic devices.

If any major issues are present that cannot be quickly corrected, the device should be removed, BMV initiated, and further management performed according to the Difficult and Failed Airway Algorithms presented in Chapter 5. If the provider concludes that critical ventilation is taking place, oxygenation should then be considered.

OPTIMIZING EGD FUNCTION

Once general function has been assessed and assured, the provider can focus on optimizing the situation. Ventilators may be employed just as if the

patient were intubated. A ventilator will free up hands and assure consistent, lung protective ventilation as appropriate for the patient's condition as well as the precise application of PEEP; tens of thousands of patients are managed in this fashion in the operating room every day. Reassessment for air leak should take place after any changes in ventilator parameters. Patients should receive appropriate analgesia and sedation, and neuromuscular blockade, as appropriate, just as if they were intubated with an ETT. Patients should be routinely monitored for common complications of any positive pressure ventilation, such as pneumothorax. A gastric tube should be inserted if a conduit exists. All "second-generation" EGDs facilitate gastric tube placement, although not all EMS providers that place these devices are allowed to perform gastric decompression or stock the appropriate-sized gastric tubes. Bite blocks should be used for spontaneously breathing patients if the EGD does not have an integrated one.

WHEN TO CONSIDER SEMIELECTIVE EXCHANGE

When a device is clearly not working and troubleshooting, as discussed previously, is unsuccessful, the decision to remove it is easy. However, the decision to remove a functioning EGD (ie, a semielective exchange) is much more challenging, and semielective exchange for an ETT is not without risk.

The reason the device was initially placed should be considered. If the EGD was placed as a matter of protocol, then a routine airway assessment should be performed using the tools and mnemonics presented in Chapter 5. If the EGD was placed by an experienced provider after one or more failed intubations, then the airway should be considered difficult regardless of other predictors.

The expected clinical course for the patient must also be considered. If the patient requires urgent imaging or a critical procedure, these should not be delayed if the device is functioning and adequate gas exchange is taking place. If the patient has a deteriorating upper airway condition, such as a thermal inhalation injury that is anticipated to eventually preclude EGD functioning, then the EGD should be exchanged as soon as possible. If the patient is headed emergently to the operating room, then it may be

reasonable to defer exchange to anesthesia providers. If, on the other hand, the patient is going to procedural location such as the interventional radiology suite or the cardiac catheterization lab, then the threshold to exchange for an ETT is lowered. These are all decisions that should be made in consultation with the providers accepting the patient.

Finally, if the patient is being transferred between institutions, the threshold for intubation is also lowered. It is reasonable to transfer a patient with a well-functioning EGD in place if:(i) the exchange is predicted to be difficult; (ii) the clinical condition is not likely to change over the course of transport such that the EGD would no longer be expected to provide effective oxygenation and ventilation; and (iii) it is not expected the EGD would remain in place long enough to risk ischemic mucosal injury. This decision should be made in conjunction with the receiving hospital, transport team, and transport agency medical director whenever possible.

HOW TO PERFORM A SEMIELECTIVE EXCHANGE FOR AN ETT

We strongly discourage rushing to remove an EGD until the airway is thoroughly assessed and device-specific plans can be made. The techniques available for exchange will vary according to the attributes of each device (**Table 14.1**), available equipment, expertise, and the clinical situation.

TABLE 14.1 Attributes of Common EGDs and Selected Exchange Techniques

Device	Type	Blind Passage of ETT Through EGD Lumen	Visualized Passage of ETT Through Lumen Using Endoscope or Intubating Stylet	Use of the Aintree Catheter for Exchange
Combitube	Dual balloon Dual lumen Retroglottic	Not possible	Not possible	Not possible
King Laryngeal Tube	Dual balloon Single lumen Retroglottic	Not possible	Not possible	Possible
King iLT-D	Dual balloon Single lumen Retroglottic	Possible Reliability not established	Possible	Possible

LMA Unique	Supraglottic	Not reliable	Possible	Possible
LMA Supreme	Supraglottic	Not possible	Not possible	Difficult
LMA Fastrach	Supraglottic	Reliable	Possible (flexible endoscope only)	Possible
Intersurgical i-gel	Supraglottic	Not reliable	Possible	Possible
CookGas air-Q	Supraglottic	Not reliable	Possible	Possible
Ambu AuraGain	Supraglottic	Not reliable	Possible	Possible

Removal With Routine Intubation via Direct/Video Laryngoscopy

An EGD can always just be deflated and removed. This approach may be utilized with any EGD when an anatomically difficult airway is not anticipated and patient physiology is favorable or when sufficient equipment or expertise for a more secure exchange is not available. Decompress the stomach first, whenever possible. The patient should be appropriately sedated and paralyzed as during an RSI procedure. Reinsertion of the same EGD is a consideration if intubation proves difficult or impossible, provided the cuff was not damaged when removed.

Working Around the Device and Performing Intubation With Direct/Video Laryngoscopy

This approach is particularly useful in situations where a retroglottic EGD such as the Combitube or King LT is in place. In these cases, the device effectively blocks the esophagus, limiting the potential for tube misplacement. With the Combitube the pharyngeal balloon may be deflated, whereas the esophageal balloon is left inflated to minimize regurgitation. With the King LT both balloons are connected to a single inflation port, and therefore both balloons are deflated simultaneously. Gastric decompression should take place whenever possible before airway manipulation. These devices may then be swept far to the left side of the mouth to allow for laryngoscopy and tube passage. Use of standard geometry video

laryngoscopy with an ETT introducer (bougie) may be helpful because the working space that remains is often tight (**Fig. 14.3**). If this strategy proves challenging but sufficiently reassuring airway anatomy has been revealed, the device may be removed entirely to allow for more working space to perform the intubation. If intubation is unsuccessful and the airway anatomy is severely compromised, the EGD may be rapidly reinflated to allow for further ventilation and oxygenation.

Figure 14.3: Exchange of a King laryngeal tube. The cuff is deflated after optimal preoxygenation. The gastric tube is left in place. The laryngeal tube is swept to the far side of the mouth and laryngoscopy is performed, in this case with standard geometry VL and a bougie.

Blind Exchange

The only EGD that has proven to facilitate blind intubation reliably and safely without the need for adjuncts is the Intubating Laryngeal Mask Airway (I-LMA, Fastrach LMA), using the techniques described further on. It may also be reasonable to make one attempt at blind intubation through

other supraglottic devices such as the air-Q or i-gel, although the reported success rates are generally much lower than with the Fastrach. The new Intubating Laryngeal Tube (iLTS-D) also permits blind intubation, but the success rates are not yet well established. Another hypothetical approach to blind intubation through an EGD would be to pass a bougie through the device, feeling for the typical tactile feedback of the anteriorly pointed coude tip bumping over the tracheal rings. If this occurs, the EGD could be removed and an ETT railroaded over the bougie in the usual fashion. We are aware of cases of airway perforation using this technique, possibly because a normally pliable bougie becomes much more rigid when protruding from an EGD and directs all the force into a small critical area. As such, we do not generally recommend this approach nor do the device manufacturers.

LMA Fastrach

The LMA Fastrach comes in three sizes (3,4,5) for patients with ideal body weight of over 30 kg and with corresponding ETT sizes of 6.0 to 8.0. The Fastrach is initially placed and utilized to provide ventilation and oxygenation. The insertion technique is not described here but is widely available on-line, in previous editions of this text, and in other airway management references. Once the saturations are adequate, blind intubation may be attempted using these steps. The technique is easiest with the manufacturer-supplied silicone-tipped and wire reinforced straight ETT, but a conventional ETT can be used if “reverse loaded.”

1. Grab the Fastrach handle firmly in the dominant hand, using a “frying pan” grip. While ventilating, manipulate the mask with a lifting motion in a direction similar to that used for direct laryngoscopy (ie, toward the ceiling over the patient’s feet, **Fig. 14.4**). This is the Chandy Second Maneuver, which enhances mask seal and intubation success. Best mask positioning will be identified by essentially noiseless ventilation, almost as if the patient is being ventilated through a cuffed ETT.

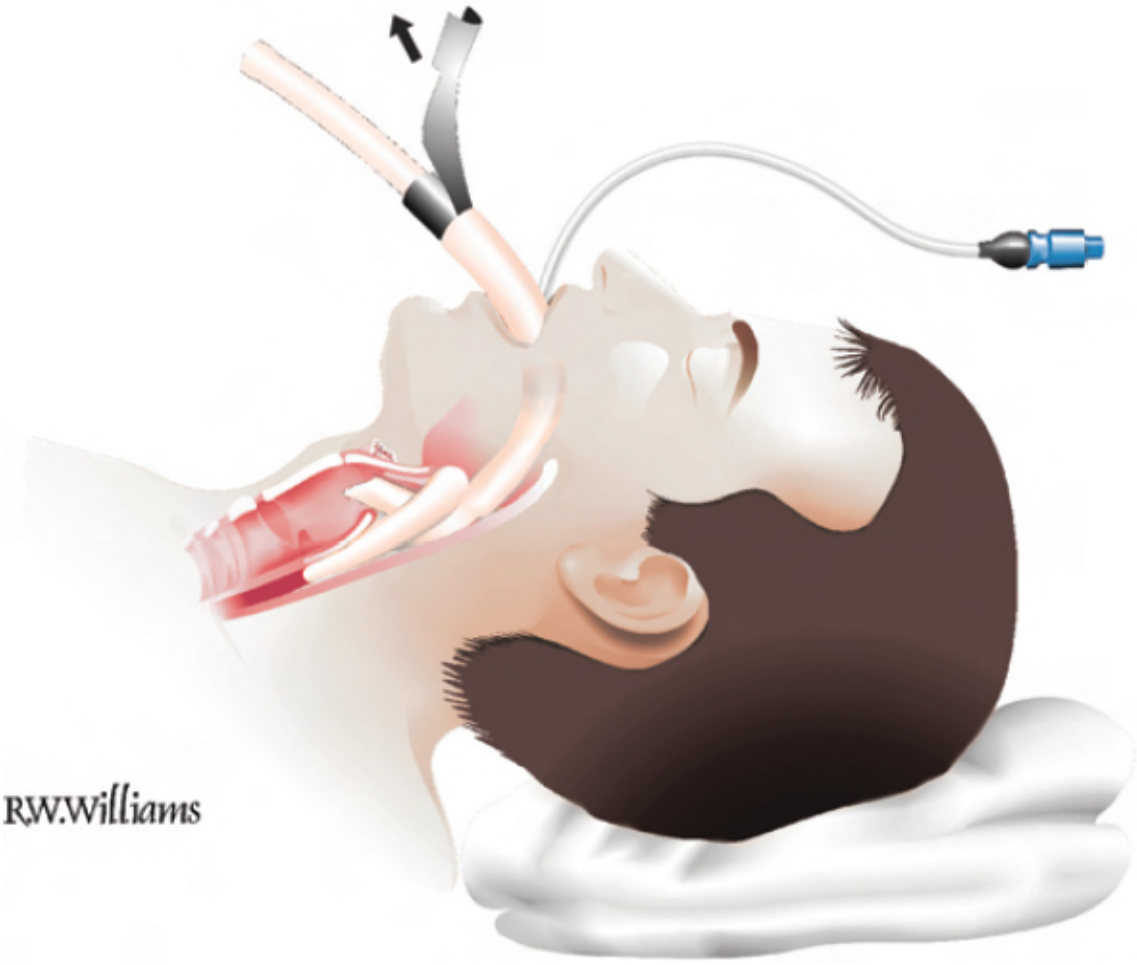

Figure 14.4: Chandy maneuver. Lift the handle of the LMA Fastrach as the endotracheal tube is about to pass into the larynx to improve intubation success.

2. Visually inspect and test the cuff of the silicone-tipped ETT that is supplied with the LMA Fastrach. *Fully deflate* the cuff (important), generously lubricate the length of the ETT liberally, and pass it through the LMA Fastrach. With the black vertical line on the ETT facing the operator (indicates that the leading edge of the bevel will advance through the cords in an A-P orientation), insert the ETT to the 15-cm-deep marker, which corresponds to the transverse black line on the silicone-tipped ETT. This indicates that the silicone tip of the tube is about to emerge from the LMA Fastrach, pushing the epiglottic elevating bar up to lift the epiglottis. Use the handle to gently lift the LMA Fastrach as the ETT is advanced until intubation is complete. Inflate the ETT cuff and confirm with capnography.

3. After intubation, the Fastrach cuff should be deflated but does not need to be removed emergently; it may be left in place until the clinical situation is stabilized and experienced help is available. The process for removal of EGDs over an ETT is discussed next.

Endoscopic Exchange

Endoscopic exchange is the ideal approach when the necessary equipment and expertise and time are available, and the in situ EGD is one that will accommodate an ETT (see Table 14.1). Because such exchanges are usually undertaken only when the EGD is functioning well as a ventilation conduit to allow the necessary time, the orifice is likely sitting directly in front of the glottic opening, and this makes the procedure simple and highly successful even for relative novices. Endoscopic exchange also permits continuous oxygenation that extends the safe procedural time.

Many EGDs indicate the appropriate-sized tube to use directly on the side of the device. In some cases, identifying the make and size of the LMA in use is difficult when only a portion of the EGD is visible outside of the mouth (see **Fig. 14.5A** and **B**). For this reason, communication with the team who placed the EGD is critical, as is familiarity with the appearance of various EGDs.

Figure 14.5: A: A similar arrangement with a full side view. Each EGD has distinguishing characteristics. From left to right: CookGas air-Q SP, Intersurgical i-gel, Ambu AuraGain, LMA Supreme, and King Laryngeal Tube.

Figure 14.5: B: Representative EGDs seen as they would be encountered by a provider after insertion.

We recommend first loading the well-lubricated ETT into the EGD until the cuff is within the lumen (**Fig. 14.6**), followed by inflating the balloon with just enough air to secure it there (usually about 2-3 mL). Some providers prefer an ETT that is tapered to more snugly interface with the fiberoptic endoscope. This makes passage of the ETT less likely to be hung up on the arytenoids. Genesis Airway Innovations now makes a Rescue Endotracheal Tube specifically designed for easier placement through an EGD, and it comes with an improved extender for removal, as described later.

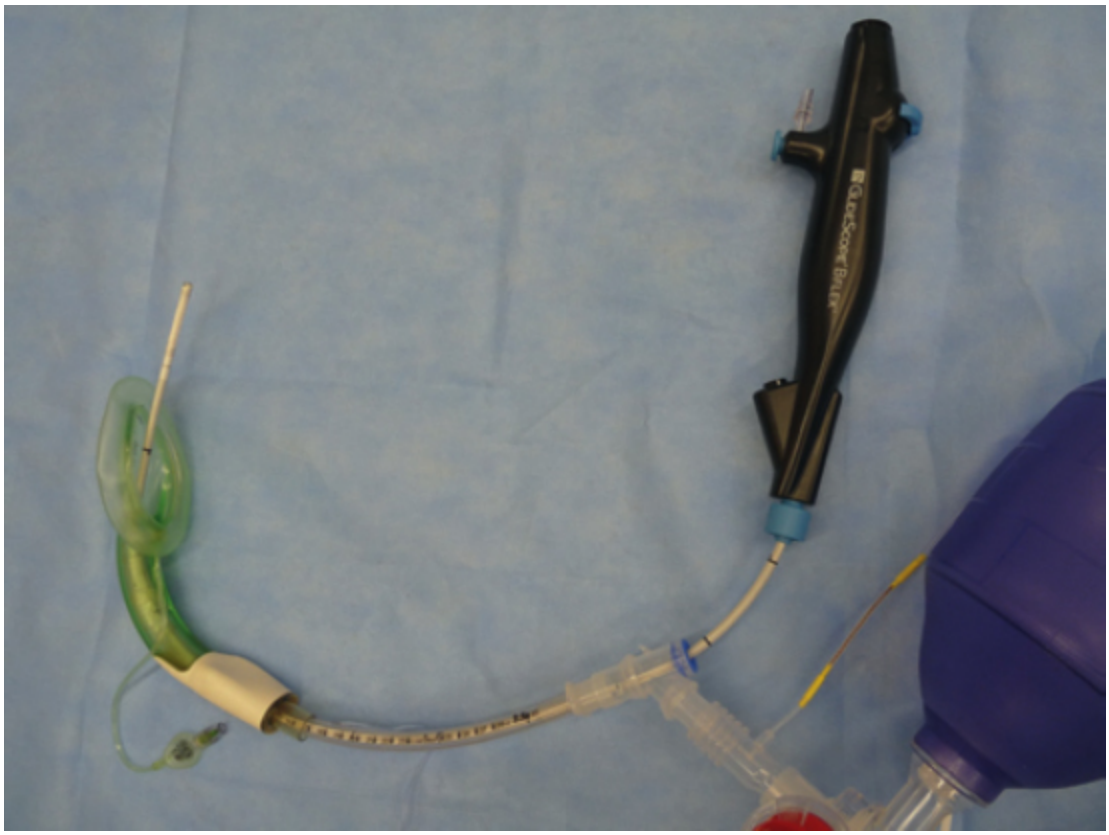

Figure 14.6: Ex vivo setup described in text in which the endotracheal tube (ETT) is preloaded into the extraglottic device (EGD) (essentially just extending the device and creating extra dead space) and a swivel adapter allows oxygenation and ventilation while the endoscope is passed into the tracheal through the ETT and EGD. Note continuous capnography monitoring as well.

Ideally, an endoscopic port adapter (ie, “bronch adapter” or “bronch elbow” or “swivel adaptor”) will be placed on the end of the ETT during these maneuvers (Fig. 14.6) to allow for continuous ventilation and oxygenation via a bag or ventilator while the endoscope is advanced. The lubricated endoscope is then advanced through the ETT and EGD lumen (**Fig. 14.7**) and visually guided into the trachea. At this point, the cuff of the ETT can be deflated to permit its passage into the trachea over the bronchoscope. The ventilator will likely sense a brief loss of volumes and trigger an alarm. Once the tube is within the trachea, the balloon is reinflated to allow full ventilation to resume. The EGD may then be removed or simply left in place. See “Removal After Intubation.”

Figure 14.7: Endoscopic intubation through an extraglottic device (EGD). An endotracheal tube (ETT) has been preloaded into an EGD, namely the Cookgas air-Q, which has been placed in a mannequin; 2 to 3 mL of air was delivered to the ETT cuff to secure it there and to provide a seal. An endoscopic port adapter is being used to maintain the ventilation circuit. A video endoscope scope is being driven through the port, through the ETT and EGD, and into the trachea with ease while maintaining oxygenation and ventilation. After the trachea has been accessed with the scope, the ETT can simply be advanced over it.

It is possible to quickly check and adjust the depth of the ET tube before removing the bronchoscope. To do so, advance the scope camera to the

carina, grasp the scope at the point it enters the bronch adaptor and withdraw while maintaining your fingers in the same position. When the distal tip of the ETT is first visualized, the distance from your fingers to the bronch adaptor is now the distance from the carina to the tip of the ETT.

For those EGDs that do not have a large enough bore to accommodate an ETT, such as the LMA Supreme or King LTS-D, an Aintree catheter (**Fig. 14.8**) or other airway exchange kit such as the Arndt Airway Exchange Catheter Kit is required if endoscopic exchange is desired. These techniques are within the realm of the emergency physician (EP) but are more complicated than the previous approach.

Figure 14.8: Intubation through an LMA Supreme. The LMA supreme does not accommodate cuffed adult ETT. Instead, a pediatric bronchoscope through an Aintree catheter can be used. Note that the airway lumen of the LMA supreme is divided by the gastric decompression drain tube. This significantly decreases usable space for an exchange. Additionally, the Aintree catheter must leave the bowl of the LMA Supreme prior to the epiglottic fins or risk being trapped by them.

The Aintree catheter is a device that resembles a hollow bougie designed to fit over a flexible pediatric endoscope yet still allowing the

scope to exit the distal end and be maneuvered. The Aintree catheter comes in an outside diameter of 19 F (6.33 mm) and an inside diameter of 4.7 mm. This is important because most adult bronchoscopes have an outside diameter larger than this. The aScope 4 Broncho Slim has an O.D. of 3.8 mm, and the GlideScope BFlex line also has a 3.8-mm version. Other versions of these two popular disposable bronchoscopes are too large to fit in the Aintree catheter. After the Aintree has been slipped over a lubricated bronchoscope, the scope can be driven through a bronchoscopy adaptor and down the lumen of the EGD into the airway with continuous ventilation, as described previously. The scope and EGD are carefully removed over the Aintree, leaving the Aintree within the trachea to be used like a bougie to guide an ETT into position. Only limited ventilation is possible once the EGD is removed, and only if the provided 15 mm adaptor is attached to the Aintree.

As with any bougie intubation, a laryngoscope should be inserted to displace the tongue forward into the mandibular fossa to keep pressure off the Aintree and prevent it from bending backward in the pharynx, because this would hinder tube passage. Maintaining the Aintree catheter within the trachea during exchange is the top priority, although it is important not to allow the catheter to pass too deeply in the bronchial tree owing to the risk of causing pneumothorax or other bronchial injury.

Exchange kits utilize similar principles but pass a wire through the working channel of the endoscope to facilitate passage of the catheter overtop after scope removal. This technique is rarely used in the ED and not described here.

If other options do not exist and the provider has a disposable bronchoscope available but does not have a compatible Aintree catheter, it is possible to use the scope “as the bougie.” In other words, after the disposable scope is driven into the airway under visualization, the wand may be cut from the head with trauma shears and used as a bougie; the wand is disposable, and there is no power running through it. Once this is done, the capability for further visualization is lost. Although this has not been rigorously studied, it has been successful in our experience in a limited number of cases. However, it is very challenging because we have found the wand to be short and not as stiff as most modern bougies.

REMOVAL AFTER INTUBATION

Removal of an EGD after an ETT has been passed through its lumen can be anxiety provoking and introduces the risk of accidentally extubating the patient. Fortunately, this step is often not mandatory. If the exchange was performed in the setting of a predicted difficult airway, it is our recommendation that any inflatable cuffs on the EGD be deflated and the device left in place until additional resources are available, which may require transfer to the ICU, operating room, or another facility.

If, for some reason, it is deemed imperative to remove the EGD urgently after it has been used as a conduit for intubation, the central tenet of the removal is to simply maintain a fixed position of the ETT as the EGD is backed out over it. Commercially produced tube exchange devices are available for the LMA Fastrach and the Cookgas air-Q. The Genesis Rescue Endotracheal Tubes include an “extender” (see **Figs. 14.9** and **14.10**) to allow for easier exchange along with continued ventilation. These come in sizes 5.5 through 8 mm and can be used with any EGD. If a commercially available device is not available, the same size or smaller ETT can be used to “extend” the length of the ETT already in place (**Fig. 14.11**). Care must be taken to avoid locking the extending ETT into the intubating ETT. This is more likely to happen if the tip of the extending tube is pressed tightly into the end of the intubating ETT. The reverse end of an ETT has been reported to serve as an extender to avoid this complication (**Fig. 14.12**).

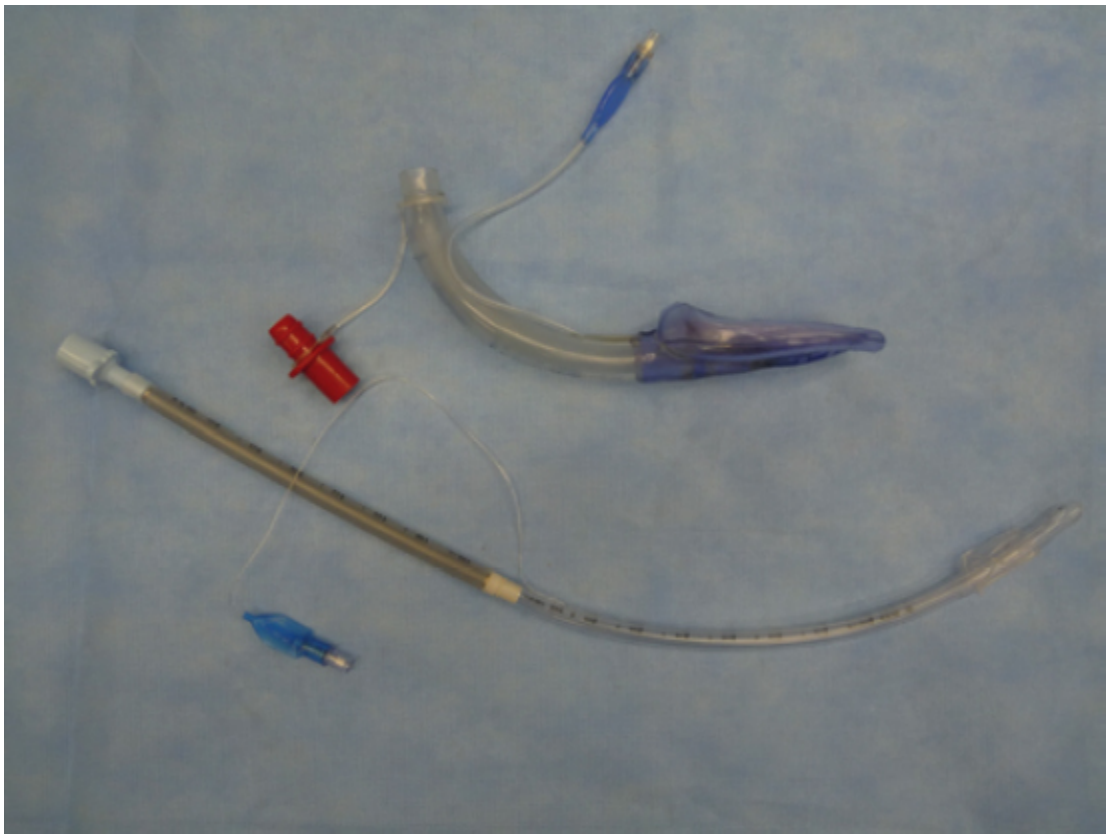

Figure 14.9: Genesis Airway Innovations Rescue Endotracheal Tube shown next to a CookGas air-Q. The extender allows for continued ventilation while the extraglottic device placed through is removed over it.

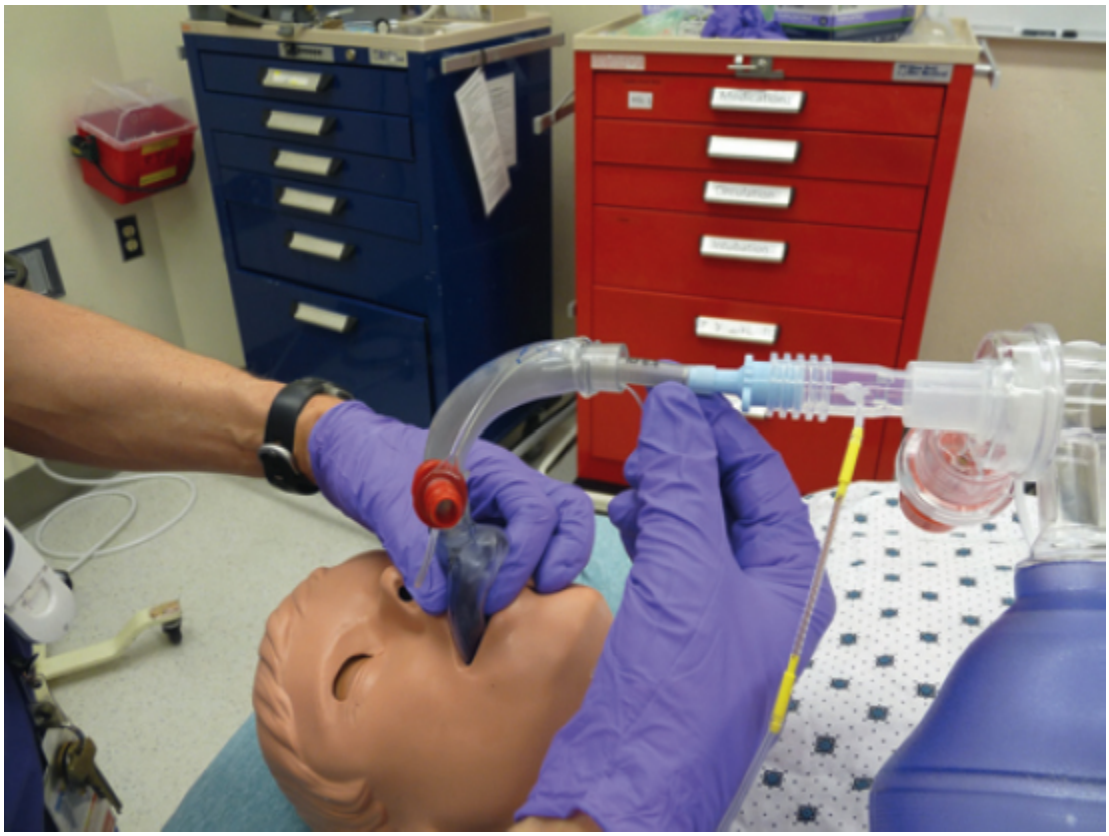

Figure 14.10: Extraglottic device (EGD) removal after intubation. An air-Q EGD is being removed over the Rescue Endotracheal Tube with continuous ventilation and capnography monitoring. The operator is ready to insert their fingers into the mouth to pin the tube against the palate.

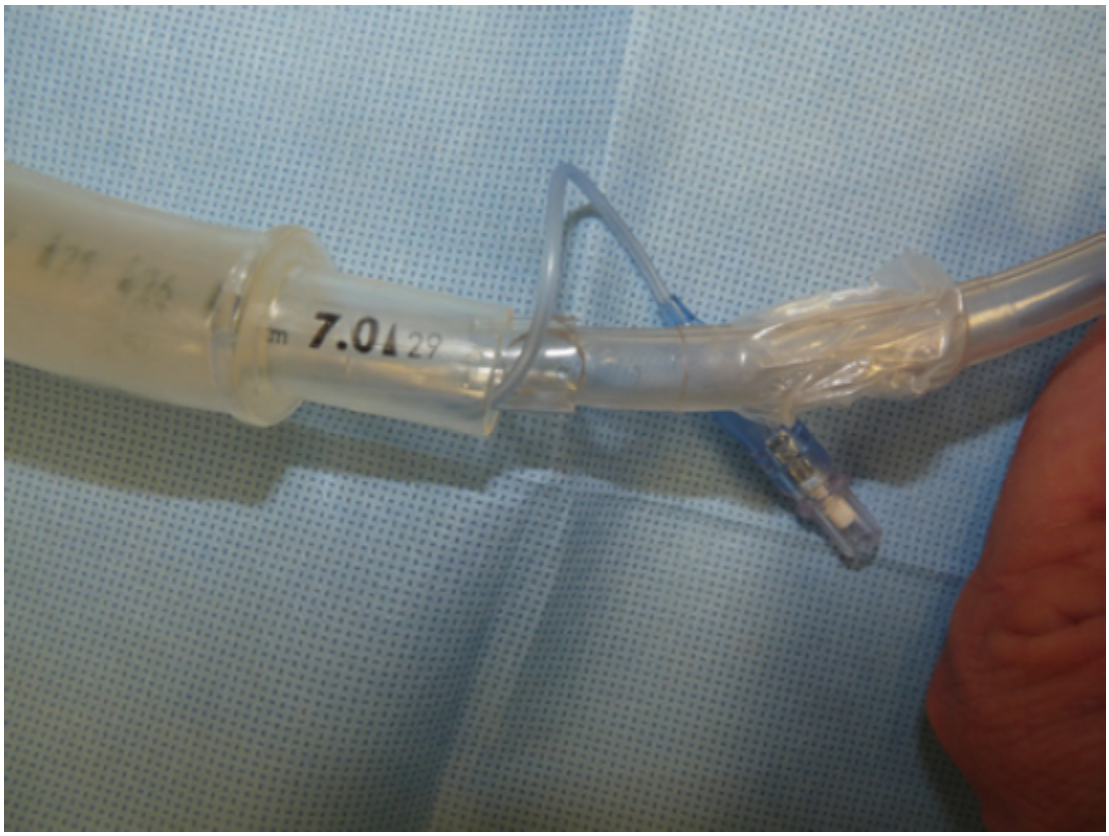

Figure 14.11: Extending the endotracheal tube (ETT) length to facilitate removal. A 0.5-mm smaller diameter ETT can be placed in the end of the primary tube to act as a “tube stop.” Care must be taken not to wedge it in place tightly to ensure easy removal.

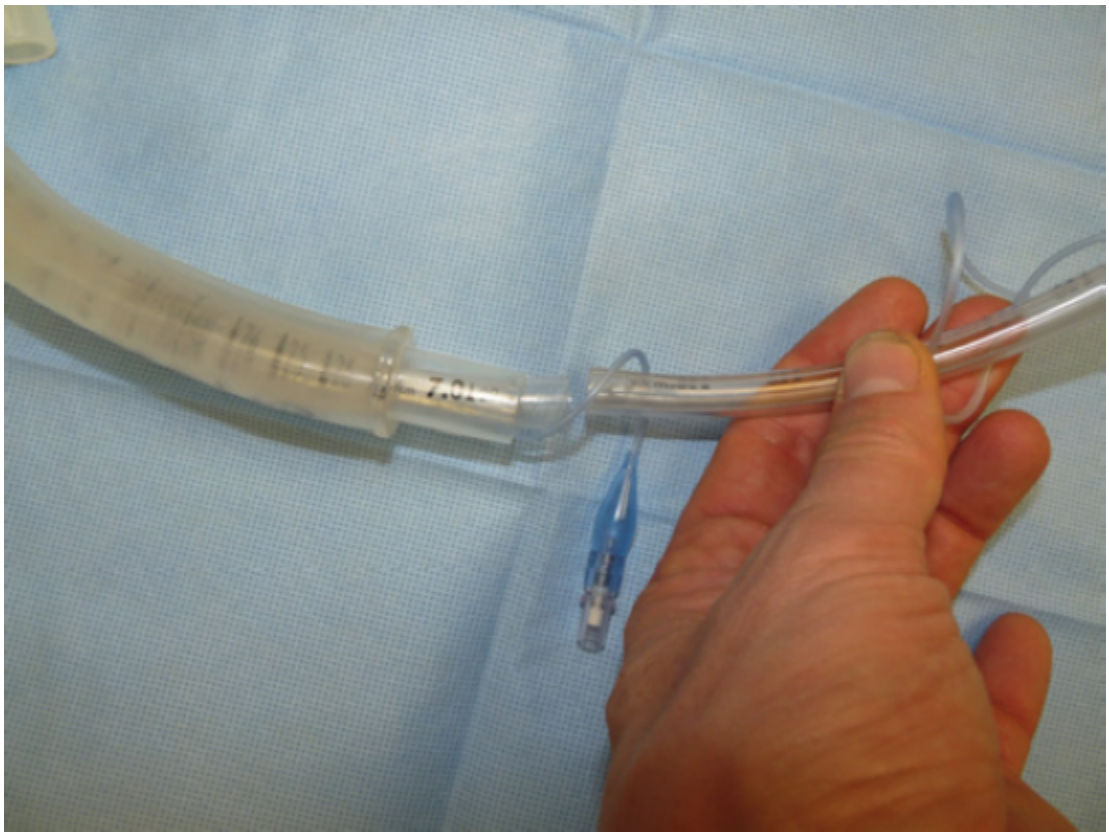

Figure 14.12: The reverse end of an endotracheal tube (ETT) being used as a tube stop; this end can be used to prevent the tip of the ETT from being wedged and stuck inside the primary ETT.

Regardless of techniques used, the pilot balloon of the intubating ETT will eventually start to enter the exiting EGD. At this point, further movement of the EGD will be hindered or risk tearing the pilot balloon or inflating tube (note: this may not apply to EGDs with very high caliber lumens). The provider should now reach into the mouth and either pin the intubating ETT to the palate or grasp the ETT so that it does not move. The extending ETT can now be removed to allow for free passage of the pilot balloon through the exiting EGD. Some providers have used McGill forceps to grasp the intubating ETT; however, care must be taken not to tear the inflating tube.

SURGICAL AIRWAY

The final means of "exchange" is to perform a surgical airway while continuing to ventilate through the EGD. This is a reasonable approach

when the EGD is providing some degree of oxygenation; very difficult intubating conditions are expected; and the time, equipment, and expertise for an endoscopic exchange is not available; or a device such as a Combitube that does not permit endoscopic passage is in situ. Although high-level evidence for this approach is lacking, it intuitively makes sense, and the authors have utilized this approach under rare circumstances and found it to be very effective.

EVIDENCE

Can a patient be pronounced dead with an EGD in place?

The question often arises regarding whether it is permissible to pronounce a patient in cardiac arrest dead after cardiopulmonary resuscitation utilizing an EGD or if a "gold standard" ETT must be placed first. The authors believe that if the EGD is ventilating the patient, it is reasonable to leave it in place. In other words, it is not necessary to exchange the device for an ETT before terminating futile resuscitative efforts.

Are emergency department providers likely to encounter patients arriving with an EGD in place?

There has been a shift in prehospital airway management practice in many communities over the past 10 years, de-emphasizing endotracheal intubation, especially for patients in cardiac arrest. Many EMS providers now place EGDs as their initial airway strategy or have a much lower threshold for moving to them as a backup.[2,3] Thus, EPs are more likely to manage patients who arrive with an EGD in place. This can pose a challenge if the EGD is not functioning appropriately or the EP is not familiar with the device itself.

Is the traditional role of the EGD expanding in the ED?

The traditional role of the EGD in the ED was only to "rescue" failed intubation. EGDs are now placed as primary airways in many EDs for patients in cardiac arrest. EGDs may also be utilized whenever it is difficult to achieve a seal for mask ventilation. Primary placement of an EGD facilitated by induction and paralysis, termed Rapid Sequence Airway

(RSA), has also been advocated as an ED option to assist with preoxygenation.[4,5]

How long can a functioning EGD safely be left in place prior to exchange?

Experience with prolonged insertion is limited, but there are situations when it is necessary in very rural areas with long EMS transport times to facilitate interhospital transfers or to await the arrival of consultants to help with predicted difficult exchanges. Braude et al. reported use of the LMA Supreme without complication for 9 hours.[6] On the other hand, complications with the LMA Fastrach have been reported after much less time.[7] In a report by Gaither et al., massive tongue engorgement was noted after a King LTS-D was in place for 3 hours.[8] Until more data is available, we try to limit noninflatable supraglottic devices (i-gel, self-pressurizing air-Q) to 6 hours, inflatable supraglottics to 4 hours, and retroglottics (King Laryngeal Tube) to 2 hours. Use of a manometer to gauge cuff inflation pressures may extend this duration.

Is blind intubation through an EGD a reasonable option?

Several studies have demonstrated the viability of visualized exchange, but the only EGD that has proven to reliably and safely facilitate blind intubation is the LMA Fastrach: the first pass success rate utilizing the recommended technique is over 90%, and success within three attempts is over 97%, regardless of obesity, secretions, or cervical precautions.[2] Blind intubation success rates with other devices such as the i-gel and air-Q have been highly variable in human studies.[9-20] It may be reasonable to practice this technique if you encounter such EGDs and consider making a single gentle attempt when the equipment for endoscopic exchanges is not immediately available.

Has exchange of King laryngeal tubes been evaluated?

One center reported high rates of surgical airways in patients that arrived in the ED with a laryngeal tube in situ.[21] A subsequent large case series using video analysis of almost 600 ED cases found that success rates with simply removing the laryngeal tube and intubating was very high, but the preferred technique was to move the device to the left side of the mouth and intubate

around it.[22] Surgical airways in this series were only required in <1% of patients that arrived with a laryngeal tube.

Is endoscopic exchange really a skill for a novice to attempt in the ED?

Although oral awake endoscopic intubation can be challenging for novices, a study found that there was no difference between novices and experts when performing endoscopic exchange through an EGD.[23]

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Section IV

Tracheal Intubation

15 Direct Laryngoscopy
16 Video Laryngoscopy
17 Flexible Endoscopic Intubation
18 Blind Intubation Techniques
19 Emergency Surgical Airways

CHAPTER 15

Direct Laryngoscopy

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Steven C. Carleton

Leslie V. Simon

DIRECT LARYNGOSCOPY

In 1913, Chevalier Jackson and Henry Janeway both published articles describing the use of direct laryngoscopy (DL) for tracheal intubation. More than 100 years later, video-assisted laryngoscopy has become the predominant technique; however, DL will forever remain a required skill for emergency physicians. DL equipment is inexpensive and universally available. With the advent of video laryngoscopy (VL) and mounting evidence that VL improves intubation performance and safety, many experts believe that the most efficient way to teach and maintain DL skill is by using a standard geometry (Macintosh-shaped) video laryngoscope (SG-VL), which allows the opportunity for DL mechanics and direct visualization but with the added benefit of immediate recourse to VL if the situation calls for it. With this approach, the instructor supervises by viewing the VL monitor (see Evidence section). In addition, devices that allow both DL and VL may be best for optimizing first-attempt success, because VL can be used to overcome anatomic difficulty and DL can be used when the VL camera becomes soiled with secretions, blood, or vomitus.

BASICS OF DIRECT LARYNGOSCOPY

The concept of DL is simple: Create a straight line of sight from the mouth to the larynx in order to visualize the vocal cords. The tongue is the greatest obstacle to DL. The laryngoscope is used to control the tongue and displace

it out of the line of sight. A laryngoscope consists of a handle, a blade, and a light source. It is used as a left-handed instrument regardless of the operator's handedness. In general, DL blades are either curved (Macintosh) or straight (Miller) (**Fig. 15.1**). Both blades come in a variety of sizes, from newborn to large adult, with sizes 3 and 4 commonly used in adults. Macintosh blades have a gentle curve, a vertical flange for displacing the tongue, and a relatively wide square tip capped with a small knob. Variations of the original Macintosh blade design, which include a smaller vertical flange and a shorter light-to-tip distance, have also been manufactured. The vertical flange height of the size 3 and 4 blades is similar, making it reasonable to start with the longer size 4 blade in most adults. Curved blades are intended to be advanced into the vallecula, and when the knob on the tip makes contact and depresses the midline vallecular fold (and the underlying hyoepiglottic ligament), the epiglottis elevates, exposing the vocal cords (**Fig. 15.2**).

Figure 15.1: Macintosh (top) and Miller (bottom) laryngoscope blades. The curved blade is a size 4 German Macintosh, which is a good blade for routine use in adults, unlike the American design, which has a taller flange height. The straight blade is a size 3 Miller, for

normal-sized adults. Most Miller blades have the light on the left side (as shown here), which can embed in the tongue, but better designs place the light on the right side of the blade.

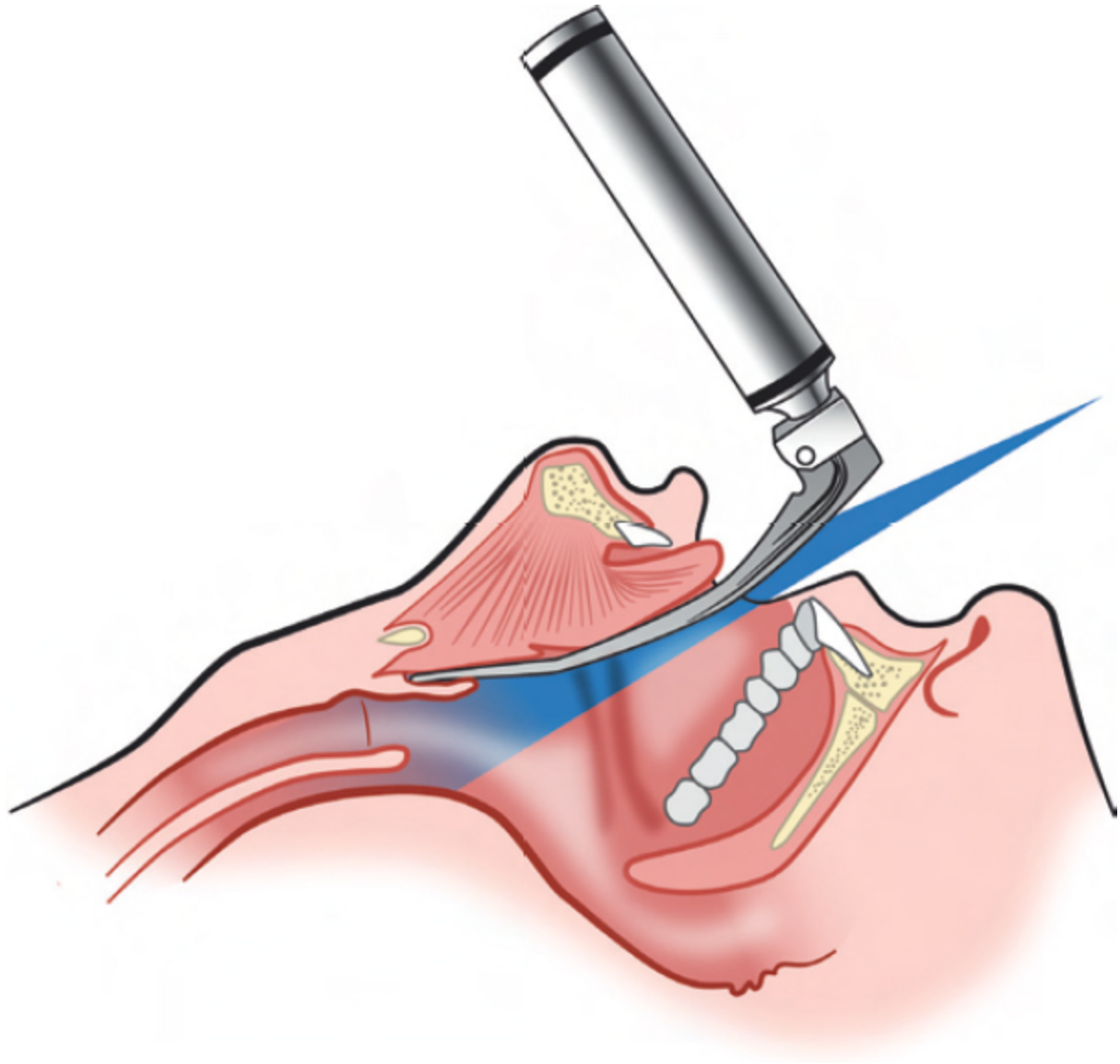

Figure 15.2: Direct laryngoscopy with a Macintosh blade. Note that the tip of the blade is properly placed into the base of the vallecula and elevates the epiglottis by pushing against the hyoepiglottic ligament.

Miller blades, the most common straight blades available, have a narrower and shorter flange and a slightly curved tip without a knob. The smaller flange may be advantageous when there is less mouth opening but makes tongue control more difficult and decreases the area of displacement for visualization and tube placement. Sizes 3 and 4 Miller blades are

identical except for length, so it may be reasonable to start with the (longer) size 4 blade in most adults. Miller blades are intended to be passed posterior to the epiglottis, to lift it directly in order to expose the vocal cords (**Fig. 15.3**).

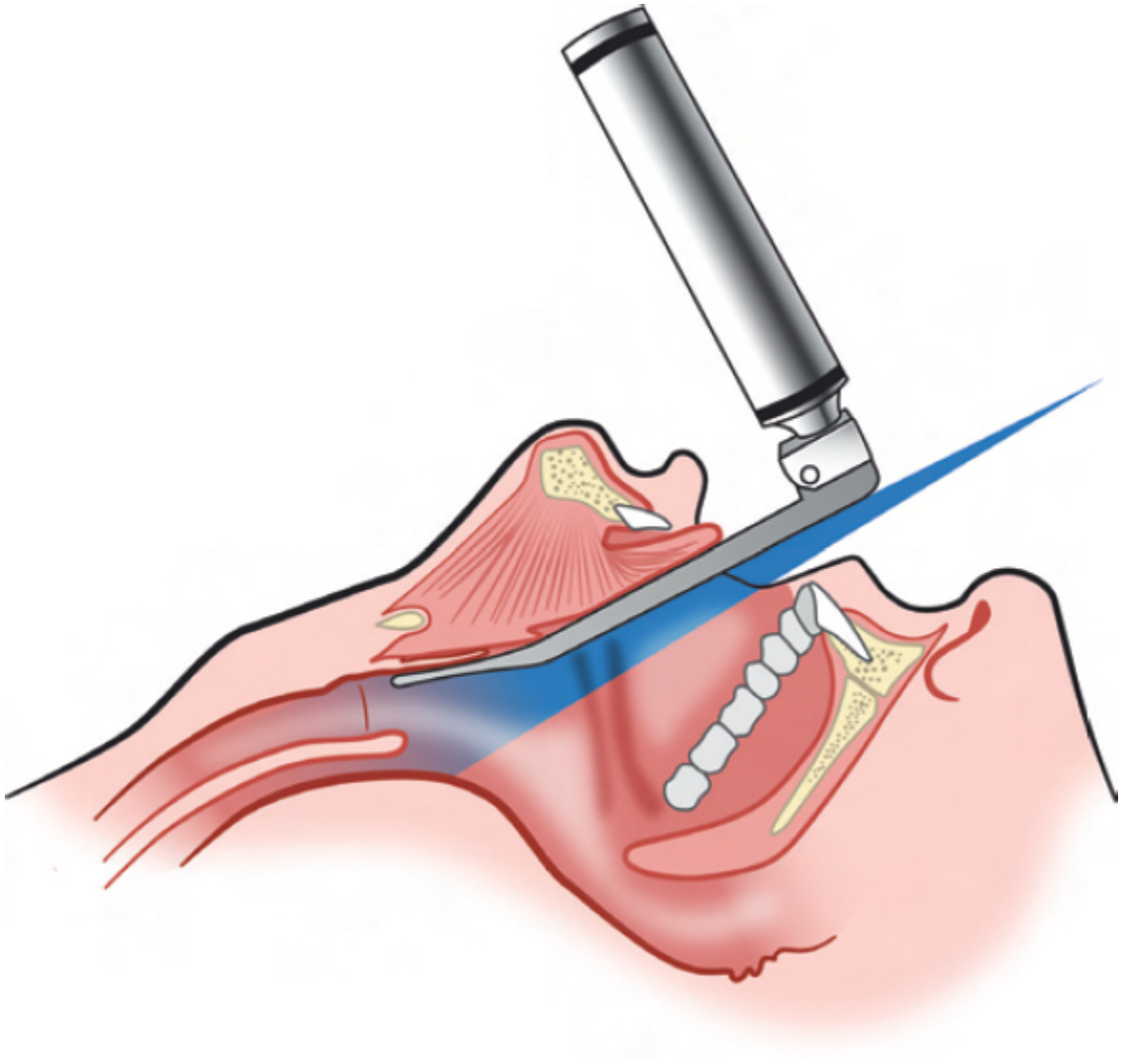

Figure 15.3: Direct laryngoscopy with a Miller blade. The tip of the blade is used to lift the epiglottis directly.

Many operators prefer the curved Macintosh blade because it is wider and allows better control of the tongue; however, the straight Miller blade may provide better visualization of the glottis in difficult airway scenarios such as a narrow interincisoral gap, limited mouth opening, or a large and

floppy epiglottis. For these reasons, it is important to master both curved and straight-blade DL techniques.

ANATOMY FOR DIRECT LARYNGOSCOPY

Tracheal intubation is accomplished by passing the endotracheal tube (ETT) through the vocal cords after visualization with laryngoscopy. Recognition of anatomic landmarks is critical to DL success. The most important landmarks are the epiglottis and vallecula, the posterior arytenoid cartilages, the interarytenoid notch, and the vocal cords. Success is more likely if the vocal cords are well visualized and a near certainty (with DL) if a full view is obtained (**Fig. 15.4A**); however, it is important to realize that tracheal intubation does not always require visualization of the vocal cords. If only the posterior cartilages are visible, the tube can be passed anterior to these structures in the midline and will usually enter the trachea (**Fig. 15.4B**). Furthermore, intubation can even be accomplished when the only visible structure is the epiglottis (**Fig. 15.4C**), especially if a bougie (ETT introducer) is used. This makes identification of the epiglottis a pivotal step in laryngoscopy. If the epiglottis cannot be identified, the likelihood of successful tracheal intubation is very low (**Fig. 15.4D**).

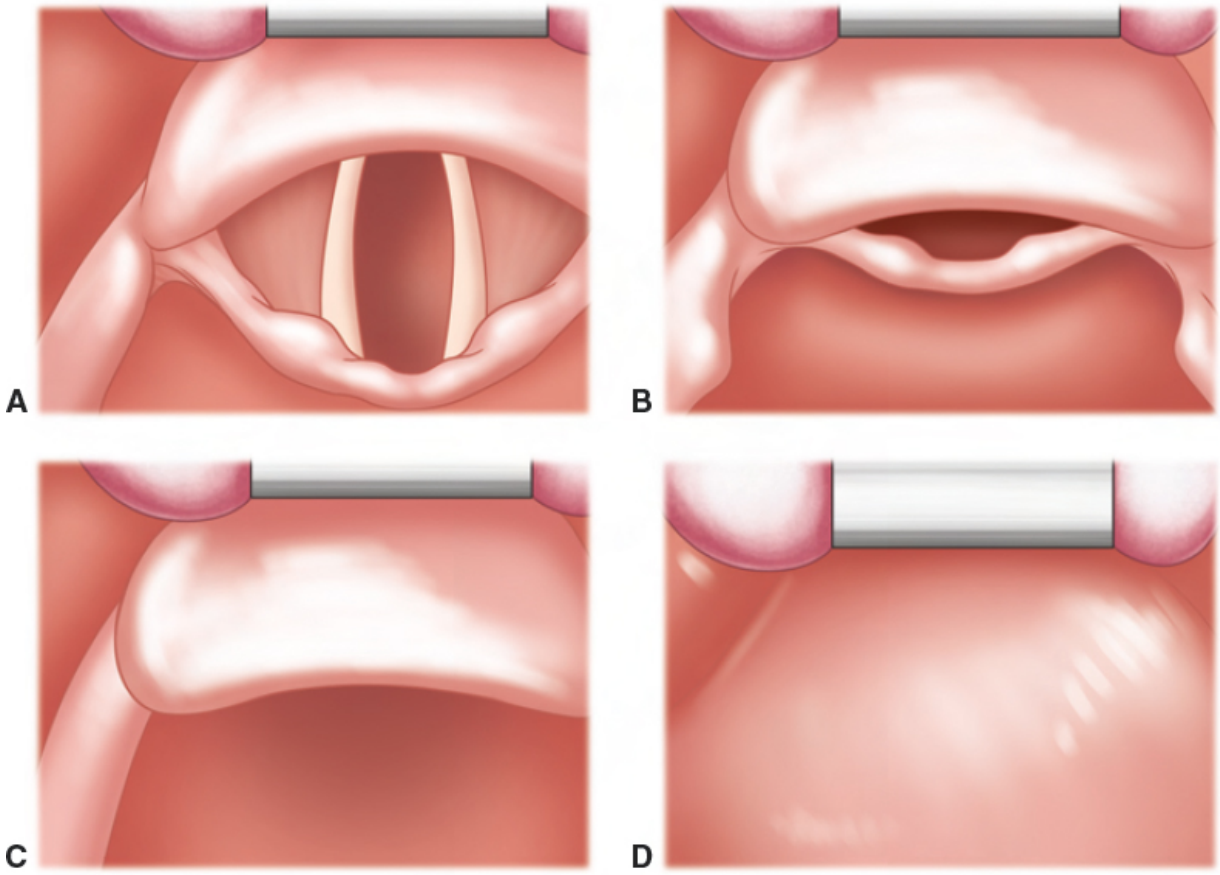

Figure 15.4: Laryngoscopic views (correlating with the Cormack-Lehane system). A: Full view of the vocal cords (grade 1). B: Only the posterior glottic structures/cartilages are visible (grade 2). C: Only the epiglottis is visible (grade 3). D: Neither the epiglottis nor the glottic structures are visible, only the soft palate (grade 4).

An important anatomic structure is the midline vallecular fold (median glossoepiglottic fold), which overlies the hyoepiglottic ligament. Although not as well visualized with DL compared with VL, this anatomic structure is critical to curved blade laryngoscopy. Applying gentle pressure to this structure with the tip of the laryngoscope blade has been shown to lift the epiglottis and improve laryngeal visualization (**Fig. 15.5**). When there is poor glottic exposure during Macintosh laryngoscopy owing to a low-hanging epiglottis, it is often because of failure of or limited engagement with the hyoepiglottic ligament (see Evidence section).

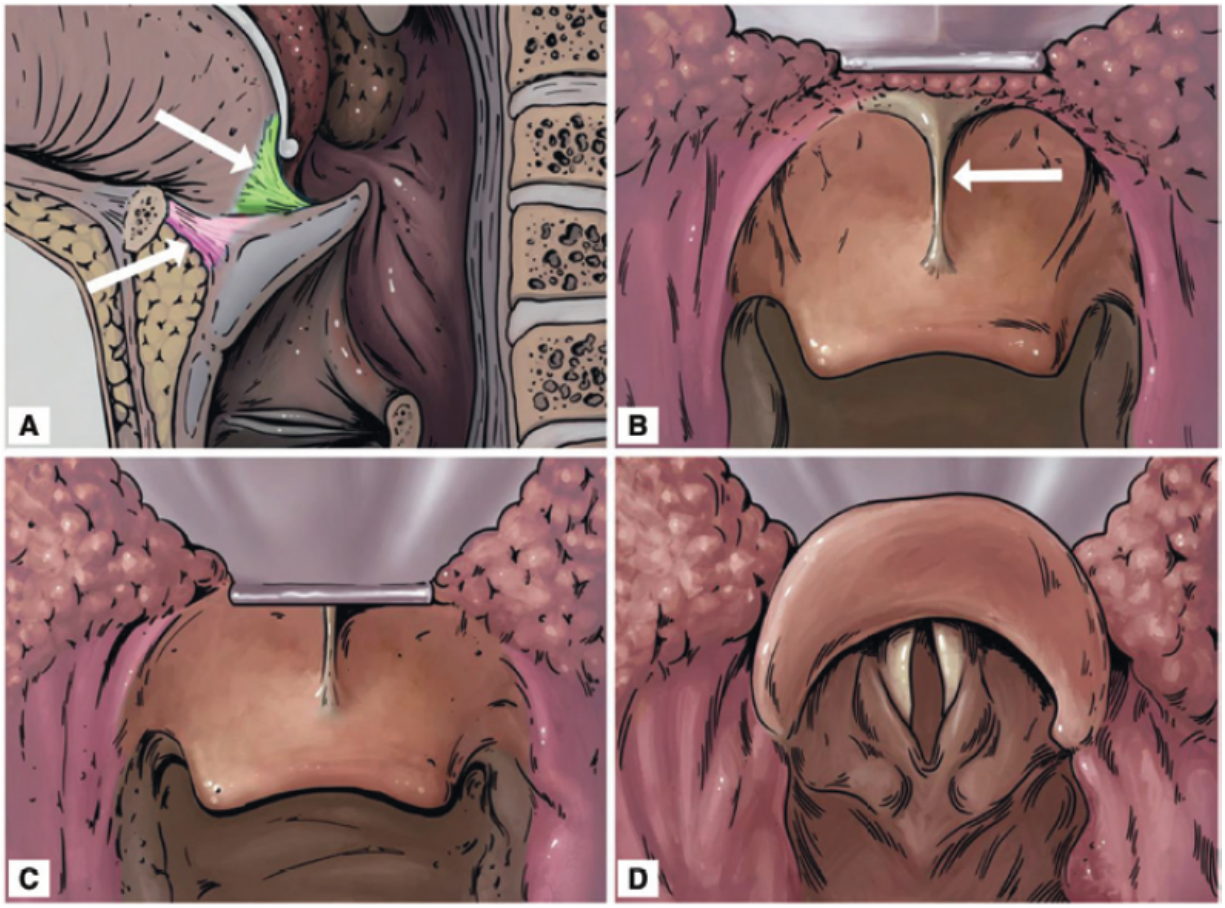

Figure 15.5: The importance of the midline vallecular fold during curved blade laryngoscopy. A: Side view of the midline vallecular fold (upper arrow) and the hyoepiglottic ligament (lower arrow). B: The midline vallecular fold as seen during curved blade laryngoscopy at the base of the vallecula. C: Articulation of the midline vallecular fold with the bulbous tip of a curved laryngoscope blade. D: Depression of the midline vallecular fold resulting in pressure on the hyoepiglottic ligament and indirect epiglottic elevation and exposure of the glottic inlet.

PREPARATION AND ASSISTANCE

Before embarking on DL for intubation, the airway manager must ensure that the following equipment is available (vascular access, patient monitors, and medications for rapid sequence intubation [RSI] are discussed separately).

- Laryngoscope blade and handle—confirmed to be working
- Lubricated ETT and backup ETT of a smaller size
- Malleable stylet

- 10 mL syringe for cuff inflation
- ETT introducer (ie, gum elastic bougie)
- Adequate suction
- Quantitative or qualitative end-tidal carbon dioxide ($ETCO_2$)
- Means to secure the tube
- Means to oxygenate and ventilate patient (self-inflating bag or ventilator)
- At least one trained assistant (ideally positioned on the patient's right)

The assistant should be prepared to do any of the following:

- Watch and report vital signs.
- Pass equipment as needed to the airway manager.
- Maintain stabilization of the cervical spine.
- Apply a jaw thrust to help lift the tongue.
- Perform external laryngeal manipulation as instructed.
- Retract the corner of the mouth during intubation.
- Assist with passage of an ETT over a bougie.

PREINTUBATION ASSESSMENT AND EQUIPMENT CHOICE

Preintubation assessment of the patient's airway, as discussed in Chapters 2 and 3 is essential and must, when time allows, be performed on every patient before administration of neuromuscular blockers. Fundamental to successful laryngoscopy is blade selection, curved or straight, that will be wide and long enough to capture the tongue during laryngoscopy, sweep it leftward and then forward into the mandibular space out of the visual field, and permit direct visualization of the airway. The larger flange of the curved Macintosh blade typically provides better tongue control than the thinner blade of the straight Miller blade. Many operators prefer a size 4 Macintosh blade for most emergency airways to ensure adequate blade length. However, choice of a laryngoscope blade and the technique used to facilitate intubation is best guided by the operator's bedside assessment, personal choice, and skill.

HANDLING THE LARYNGOSCOPE AND POSTURE OF THE OPERATOR

The laryngoscope should be held low on the handle so the proximal end of the blade pushes into the thenar or hypothenar eminence of the left hand. This grip will encourage lifting from the shoulder, keeping the elbow low, and keeping the wrist stiff during laryngoscopy. The operator should be in an upright position, with his or her arms and hands at a comfortable working height, rather than stooping or straining to reach the patient. When possible, the patient's bed should be elevated to an optimal position for the intubator, and they should step back from the patient so that his or her back is relatively straight during laryngoscopy.

PATIENT POSITIONING

Optimal head and neck positioning for DL is often described as the "sniffing position": lower cervical flexion and atlanto-occipital extension. The sniffing position attempts to align the oral, pharyngeal, and laryngeal axes of the upper airway (**Fig. 15.6A-C**). Absent contraindications, alignment of these axes is important for optimizing the laryngoscopic view. The optimal degree of lower cervical flexion brings the external auditory meatus to the level of the sternal notch or anterior surface of the shoulder. In adult patients of normal body habitus, a 4- to 6-cm pad beneath the occiput usually suffices for this purpose. Alternatively, the operator can extend and lift the head with his or her right hand during laryngoscopy to determine the optimal position empirically. The head can then be supported by folded towels or an assistant standing on the right side of the patient while the operator intubates or performs external laryngeal manipulation. In morbidly obese patients, optimal positioning will often require a ramp to be constructed from linens or pads placed beneath the upper torso, shoulders, neck, and occiput in order to align the ear canal with the sternal notch (see Chapter 43). Airway ramps are also commercially available for this purpose. In small children with a protuberant occiput, the torso may need to be raised to allow the external meatus to fall back to the desired plane (see Chapter 26). Because of individual variations in anatomy, the optimal head and neck position is often unpredictable and may require empiric

adjustment during the intubation attempt. It is critically important that some means of adjusting the patient's position be available before initiating the procedure. Understanding optimal head and neck positioning will help operators appreciate the difficulty of performing DL on trauma patients and others who must be intubated in a fixed position.

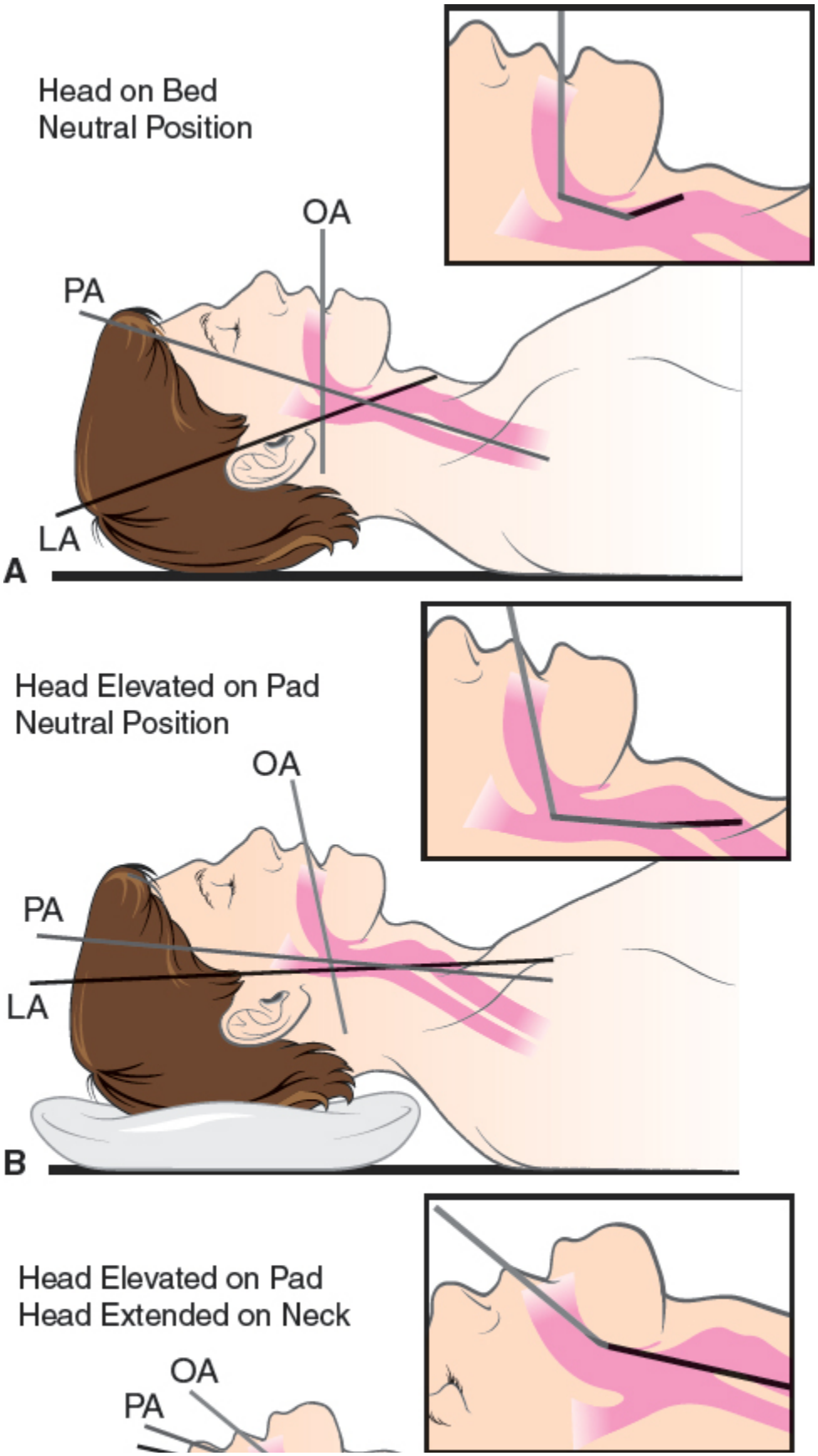
Head on Bed
Neutral Position
OA
PA
LA
A
Head Elevated on Pad
Neutral Position
OA
PA
LA
B
Head Elevated on Pad
Head Extended on Neck
OA
PA

Figure 15.6: A: Anatomic neutral position. The oral axis (OA), pharyngeal axis (PA), and laryngeal axis (LA) are not aligned. B: Head, still in neutral position, has been lifted by a pillow flexing the lower cervical spine and aligning the PA and LA. C: The head has been extended on the cervical spine, aligning the OA with the PA and LA, creating the optimum sniffing position for intubation.

STANDARD DIRECT LARYNGOSCOPY TECHNIQUE

This is the standard technique used with both curved and straight blades.

- Open the mouth as widely as possible using the scissor technique with the operator's right index finger and thumb.
- Rotate the entire laryngoscope 90° toward the patient's chest in order to vertically orient the blade for insertion between the teeth or gums.
- Insert the blade in the right lingual gutter along the inside of the mandibular molars and sweep the tongue to the left while bringing the tip of the blade to the midline (**Fig. 15.7**).

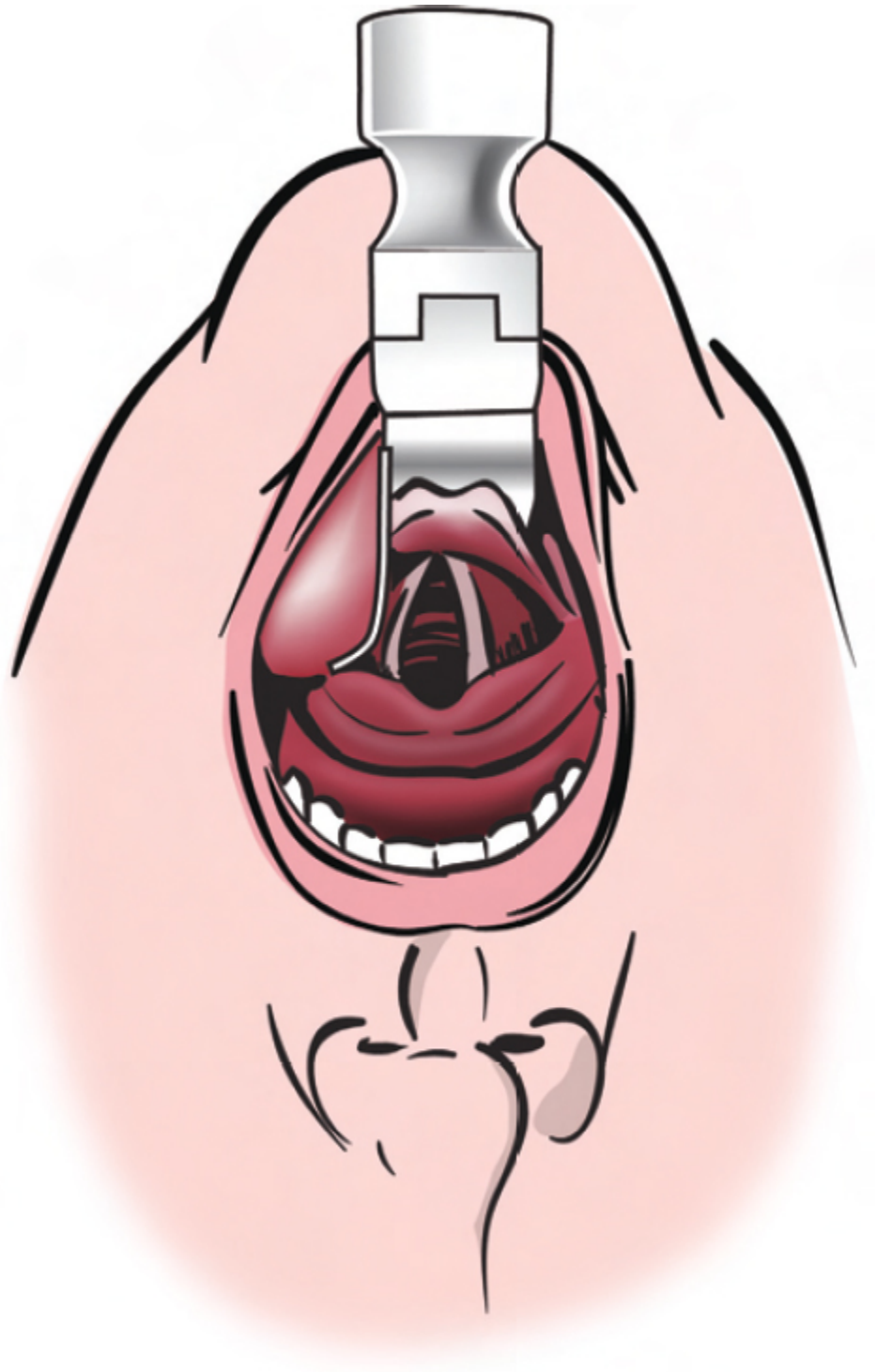

Figure 15.7: Direct laryngoscopy with a Macintosh blade. The mouth is opened wide. The tongue is well controlled and kept entirely to the left by the large flange of the Macintosh blade (this is the classic teaching). Alternatively, the blade is kept in the midline throughout the procedure (which may make it easier to progressively visualize the midline anatomy). The uvula is visualized, then the epiglottis is visualized, and the tip of the blade is pushed into the midline vallecular fold to elevate the epiglottis and

expose the vocal cords. Force is applied by lifting the entire blade upward, not by tilting the butt of the blade toward the upper incisors.

- Use a “look as you go” approach by advancing the tip of the blade down the tongue in a careful step-by-step manner, then lifting intermittently to ascertain the location of the tip in relation to anatomic structures until the epiglottis is located. *The epiglottis is the main anatomic landmark for DL* because the glottis can be consistently found just posterior and inferior to it.
- Displace the epiglottis anteriorly to allow direct visualization of the glottic structures. When using the curved blade, displace the epiglottis indirectly by pressing against the midline vallecular fold and underlying hyoepiglottic ligament at the base of the vallecula. When using the straight blade, lift the epiglottis directly with the tip of the blade (**Fig. 15.8**).

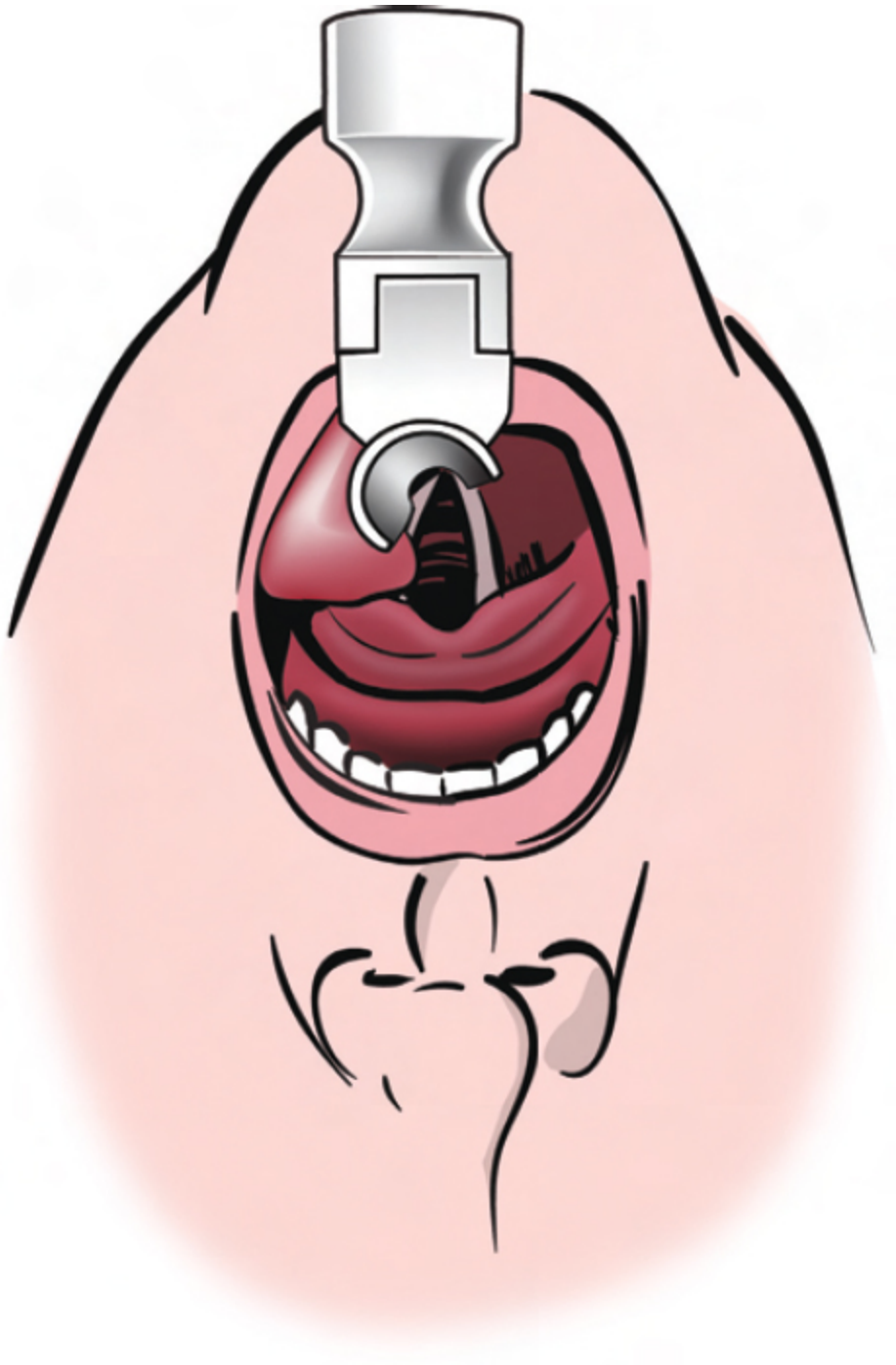

Figure 15.8: Direct laryngoscopy with a Miller blade. The mouth is opened wide, and the tongue is difficult to control with the small flange of the Miller blade, but it is kept entirely to the left. The epiglottis is identified and then lifted with the tip of the blade (so it is no longer visible here) to expose the vocal cords. Force is applied by lifting the entire blade upward, not by tilting the butt of the blade toward the upper incisors.

- *Identify the posterior cartilages and interarytenoid notch*. These structures make up the posterior border of the glottis and separate the tracheal inlet from the esophagus and are the second most important landmarks for DL. Tracheal intubation can be accomplished by passing the tube anterior to these structures, even when the vocal cords cannot be seen.
- Visualize the vocal cords, if possible.
- Pass the tube anterior to the posterior cartilages; this will place it through the vocal cords and into the trachea even if the cords are not visualized.

PARAGLOSSAL (RETROMOLAR, RIGHT OR LEFT MOLAR) STRAIGHT-BLADE TECHNIQUE

This is an alternative technique that may be useful when standard DL is unexpectedly difficult because of prominent upper incisors, a large tongue, or limited mouth opening.

- Insert the straight blade into the right corner of the mouth.
- Pass the blade along the groove between the tongue and the tonsil.
- Advance the tip of the blade toward the midline, keeping the back of the blade to the right side of the mouth adjacent to the molars (**Fig. 15.9**).

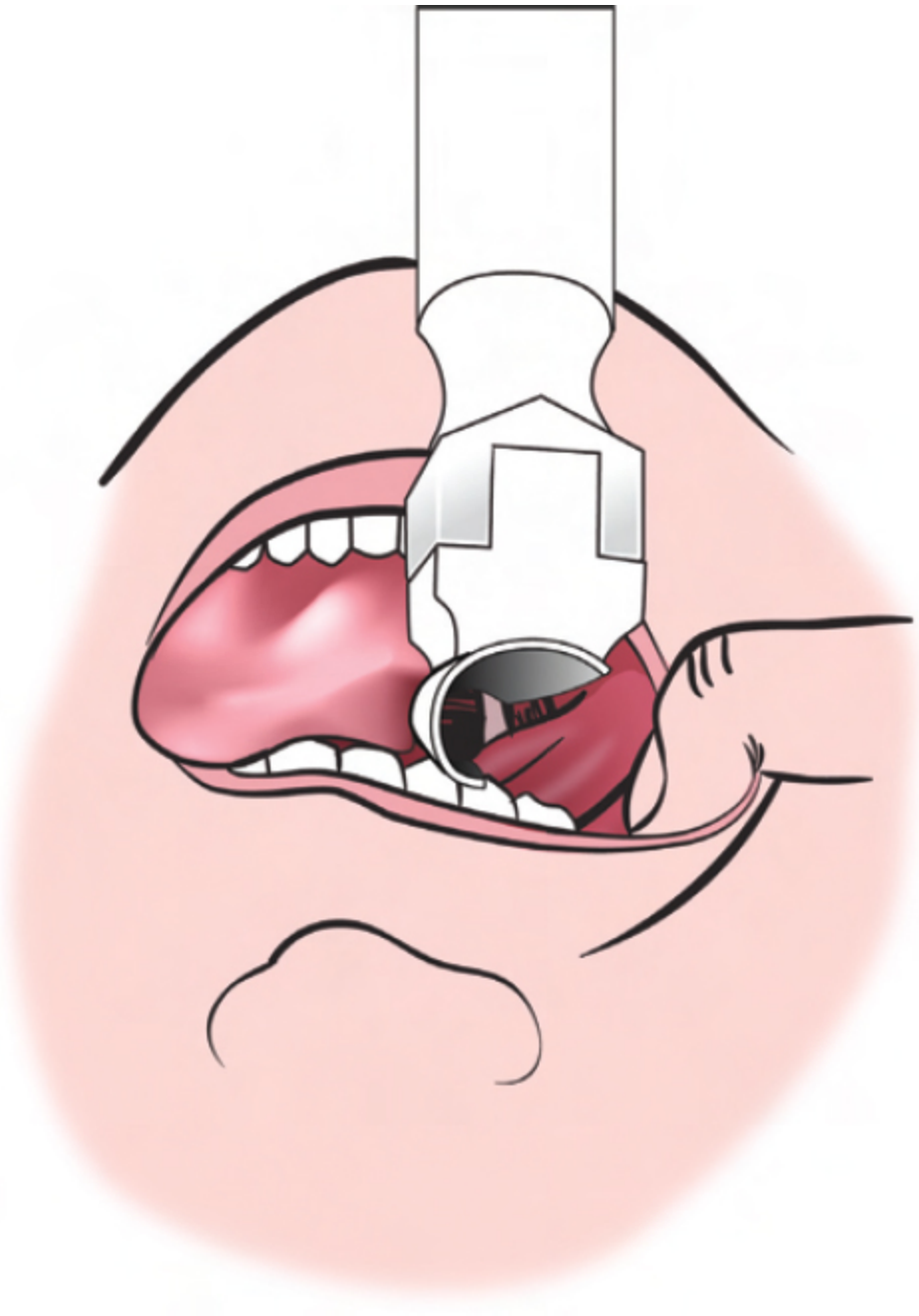

Figure 15.9: Paraglossal (retromolar, right or left molar) straight-blade technique. For a right-sided approach, the Miller blade enters the right corner of the mouth, and the tip advances toward the midline, whereas the proximal blade remains in the right side of the mouth. Note that the tongue is entirely to the left of the blade. This technique may improve glottic visualization in difficult situations but does not leave much room for passage of the endotracheal tube (ETT). Have an assistant retract the lip to create more room as shown. There is very little room for ETT passage when using this technique, and a bougie may need to be advanced down the channel of the scope.

- Alternatively, use a similar approach from the left corner of the mouth, although this is technically more challenging to complete.
- Identify the epiglottis and lift its tip to expose the vocal cords.
- Have an assistant retract the right corner of the mouth.
- Pass the tube through the vocal cords and into the trachea. Often, one needs to use a bougie down the channel of the scope with this approach because of limited space preventing ETT advancement. The bougie was specifically designed for this purpose.

BLIND INSERTION TECHNIQUE FOR THE STRAIGHT BLADE

This is an alternative technique often employed in neonates, infants, and small children, using a straight blade, or in adults when other techniques are predicted to be difficult or have failed. It may also help overcome a common challenge with straight-blade laryngoscopy, particularly by novices, when they do not recognize any structures but are unsure whether the tip is too deep or too shallow. With the use of this technique, there is only one direction to move until a recognizable landmark is visualized. There are two phases to this method: (1) blind insertion of the tip of the laryngoscope blade beyond the glottic inlet and into the esophagus and (2) visualization of the glottis during withdrawal. The potential for esophageal and tracheal injury or regurgitation resulting from opening the upper esophageal sphincter during blind insertion of the blade has not been studied, but we are not aware of any issues.

- Place the blade into the right side of the mouth and maintain the tongue to the left. This is easier to accomplish with the patient in the full sniffing position as described previously.
- Hold the laryngoscope with the fingertips and gently advance the entire length of the blade blindly toward the midline, past the base of the tongue, posterior to the glottis, and into the cervical esophagus. If there is any resistance, stop and withdraw slightly, then realign and advance completely.
- While looking into the airway, lift the blade and then slowly and deliberately withdraw until the glottis drops down into view. If the

epiglottis also drops into view, stop and readvance the blade to lift it directly and expose the vocal cords.

- Pass the tube through the vocal cords and into the trachea.

INTUBATING THE TRACHEA (TUBE PASSAGE)

If part of the glottis is directly visualized, it is typically easy to pass a tube into the trachea during DL. However, even with excellent glottic exposure, it is possible to block the line of sight with the ETT during the intubation attempt. This possibility can be minimized by inserting the tube from the extreme right-hand corner of the mouth while an assistant retracts the lip and by keeping the tube below the line of sight while advancing it toward the glottis, raising it over the posterior landmarks only during the terminal phase of insertion. Additionally, a bougie (preloaded through the ETT lumen) can be placed first, allowing guidance into the trachea during subsequent tube passage. The bougie is much thinner than a tracheal tube and is less likely to visually block the glottic inlet during intubation. Tube shape can also influence the ease of visualization during intubation. Using a malleable stylet to produce a straight tube with a single “hockey stick” bend of <35° just proximal to the balloon facilitates cord visualization during passage, by keeping the tube out of the line of sight until it passes the cords (**Fig. 15.10**). As the tube approaches the depth of the glottis, it is raised up over the posterior landmarks and passed through the vocal cords. A banana-shaped tube tends to cross the visual axis twice during insertion and may interfere with visual guidance during placement.

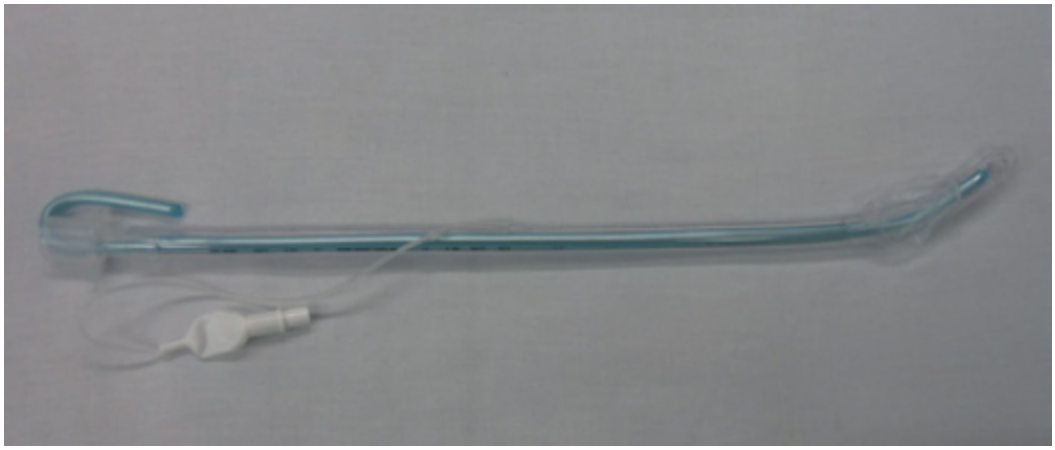

Figure 15.10: Optimal endotracheal tube (ETT)/stylet shape. A relatively straight ETT with a "hockey stick" shape, with a bend angle <35°. This shape allows passage of the ETT without blocking the line of sight.

TROUBLESHOOTING DIFFICULT DIRECT LARYNGOSCOPY

Paralysis

Neuromuscular blockade promotes optimal intubating conditions during DL in the nonarrested patient. The reflexes and muscle tone of the upper airway are difficult to overcome in patients who are sedated but not paralyzed. Airway managers should understand the indications for, and use of, neuromuscular blocking agents.

External Laryngeal Manipulation

DL is best thought of as a two-handed technique (bimanual laryngoscopy) in which the operator uses his or her right hand placed externally on the thyroid cartilage overlying an assistant's hand to manipulate the internal glottic view (**Fig. 15.11**). Backward, upward (cephalad), and rightward pressure (BURP) on the thyroid cartilage by an assistant can improve glottic visualization during laryngoscopy but is not guaranteed. Optimal external laryngeal manipulation (OELM) by the laryngoscopist is even better than BURP by an assistant because the operator gets immediate feedback and can quickly determine which movements provide an optimal view. These movements might include BURP but can also involve any movement that improves visualization of the glottis. Firm downward pressure on the thyroid cartilage moves the vocal cords posteriorly into the line of sight of the laryngoscopist. Also, during curved blade laryngoscopy, downward pressure on the thyroid cartilage helps to drive the tip of the laryngoscope into the hyoepiglottic ligament, further lifting the epiglottis out of the visual axis. When the laryngoscopist finds the best view, the assistant can maintain the optimal position while the ETT is placed. If the assistant's fingers were not on the thyroid cartilage first, there is a significant chance that the view will be lost when a changeover occurs from the intubator maintaining the position to the assistant. BURP may still be preferred in teaching situations if the intubator is not yet skilled in OELM. Bimanual laryngoscopy should

not be confused with cricoid pressure (Sellick maneuver), which is undirected posterior displacement of the cricoid ring, historically performed during BMV (Bag-Mask Ventilation) to avoid regurgitation. Cricoid pressure can worsen glottic view and impede tube passage when applied incorrectly.

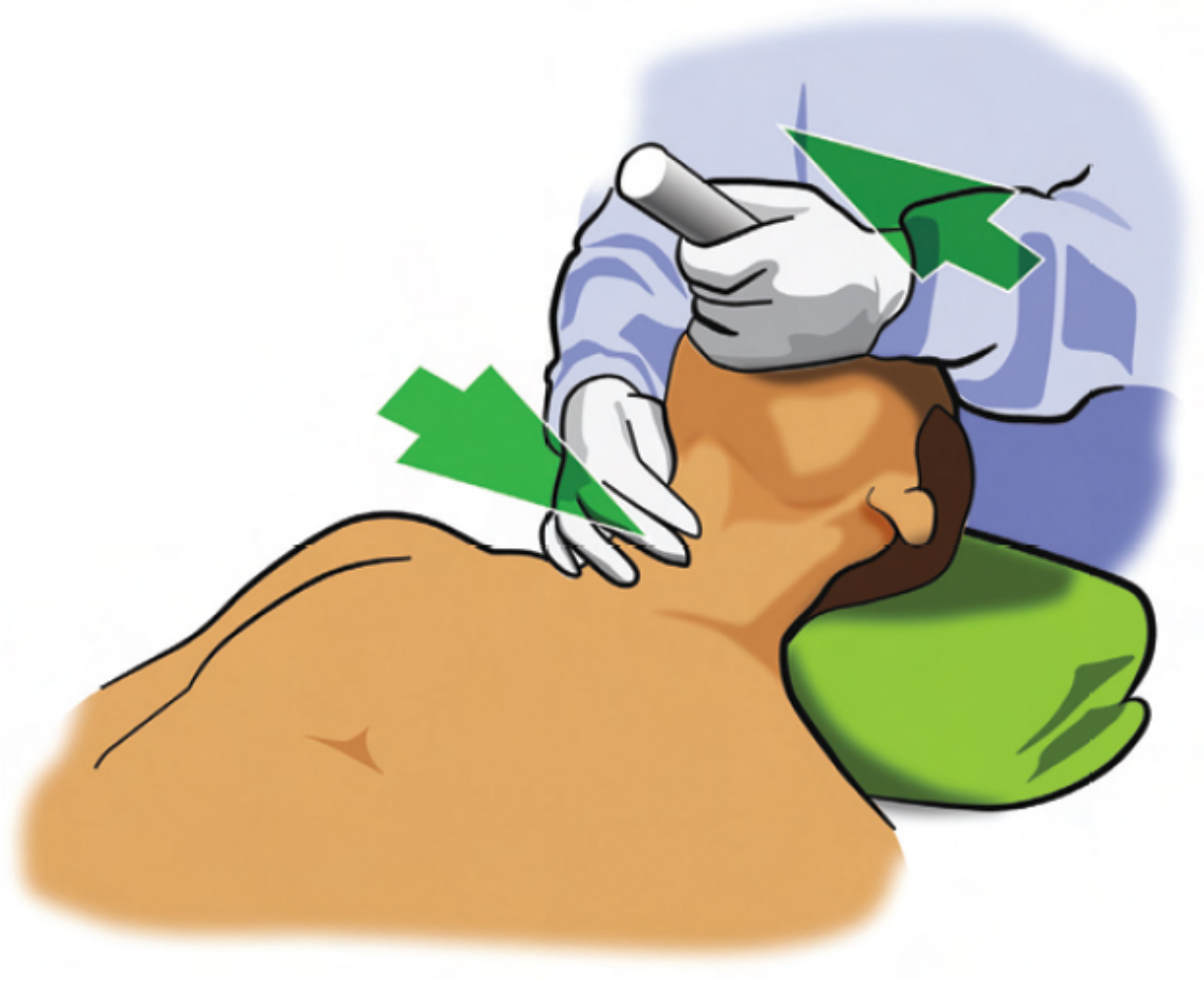

Figure 15.11: Bimanual laryngoscopy. The laryngoscopist uses his or her right hand to manipulate the thyroid cartilage. Optimal external manipulation often involves firm pressure on the thyroid cartilage and movement to the right (backward, upward [cephalad], and rightward pressure). The advantage of the laryngoscopist performing this maneuver (not an assistant) is that he or she gets immediate visual feedback and can quickly determine what constitutes *optimal* external manipulation.

Positioning

When glottic visualization is poor, the operator can extend and lift the head with his or her right hand during laryngoscopy (when in-line stabilization is

not required) to determine the optimal position, then have an assistant hold the head if necessary. More extensive patient repositioning will require abandoning the first attempt, and it may be very difficult to reposition larger patients after RSI medications have been administered. This highlights the importance of optimal patient positioning prior to RSI, especially in larger patients.

Mandibular Advancement

Mandibular advancement by an assistant during laryngoscopy moves the lower incisors anterior to the upper incisors and may help displace the tongue and improve glottic visualization. A practical way to accomplish this is to have the assistant stand at the patient's side and perform a two-handed jaw thrust from below while taking care not to interfere with the intubator. This is especially helpful when the patient is large and the intubator is small and lacks the strength to move the tongue and mandible with the laryngoscope blade.

Bougie (Endotracheal Tube Introducer)

A bougie is a simple, inexpensive adjunct that can improve intubation success when visualization of the glottis is difficult (**Fig. 15.12**). It is most helpful when the epiglottis is visualized but the vocal cords and posterior cartilages cannot be seen, Cormack-Lehane Class III. The bougie is a long (60-70 cm), narrow (5 mm), flexible plastic or spun nylon device with a fixed 40° bend at the distal end (Coudé tip). Some brands come preshaped but for those that are packaged straight, insertion is often facilitated by making a 60° anterior bend approximately 10 to 15 cm from the distal tip (Fig. 15.12, inset). The bougie is held with the tip pointing upward. Under visual guidance with a laryngoscope, it is passed just under the epiglottis and upward into the tracheal inlet or where the intubator believes the inlet to be (**Fig. 15.13**). Tracheal placement may result in palpable vibrations of the introducer as the Coudé tip bumps against the anterior tracheal rings during insertion. Alternatively, tracheal placement can be confirmed by gently advancing until a hard stop is encountered at about 40 cm of insertion. Placement in the esophagus provides no such hard stop. The ETT is placed over the bougie by the intubator or an assistant until the proximal

end of the bougie is grasped while the operator keeps the laryngoscope in place, continuing to displace the tongue into the mandibular fossa. This is a critical, and often neglected, point (**Fig. 15.14**). The operator then passes the ETT distally while the assistant holds the butt end of the bougie to prevent further advancement. Alternatively, the operator may stabilize the bougie with their left hand along with the laryngoscope once it has been passed through the cords. As the tip of the ETT approaches the glottis, the laryngoscopist should rotate it counterclockwise to facilitate passage through the vocal cords and to avoid the tip hanging up under the ridge of the arytenoid cartilages (**Fig. 15.15A-C**). It may be best to use the bougie on every emergency intubation. Because there is little, if any, downside and there is a high incidence of unanticipated difficult airways in this setting, regular bougie use would allow the intubator and assistants to maintain competence and comfort with this technique.

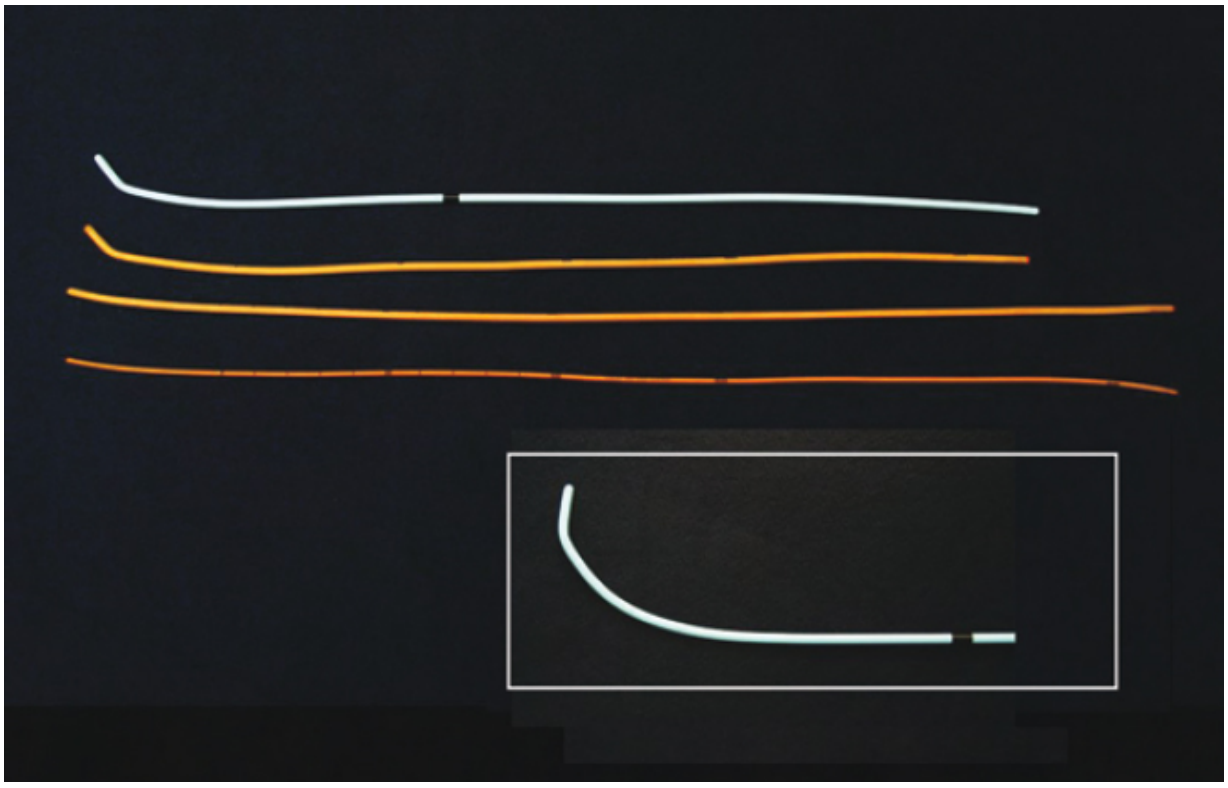

Figure 15.12: Bougies. The classic gum elastic bougies (yellow) are reusable, 60 to 70 cm long, and available with straight and Coudé tip designs. A reusable (blue) polyethylene introducer is available with a Coudé tip and is 60 cm in length. Adult tracheal tube introducers are 5 mm in diameter. A thinner pediatric introducer can accommodate a 4.0-mm endotracheal tube (ETT). The lower right inset demonstrates the 60° optimal curve for

attempting intubation when none of the glottic structures (only the epiglottis) can be visualized with laryngoscopy.

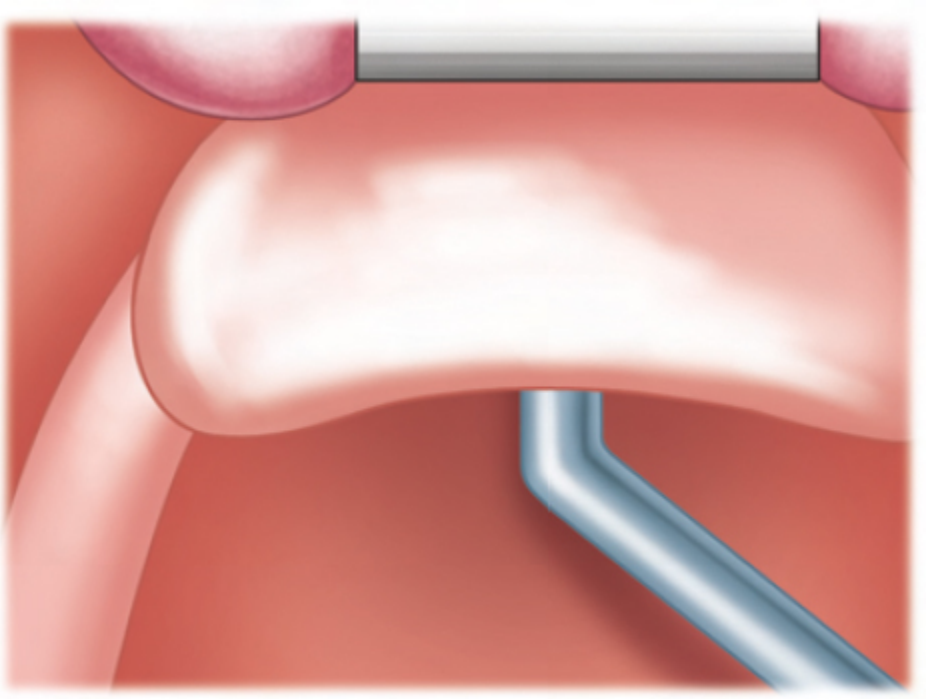

Figure 15.13: Bougie facilitating intubation with difficult (grade 3—“epiglottis only” view) laryngoscopy. The disposable blue introducer is passed beneath the epiglottis and then anteriorly and caudally through the glottic inlet. The operator can immediately confirm tracheal placement by feeling the introducer against the tracheal rings or feeling a hard stop as the introducer enters a mainstem bronchus.

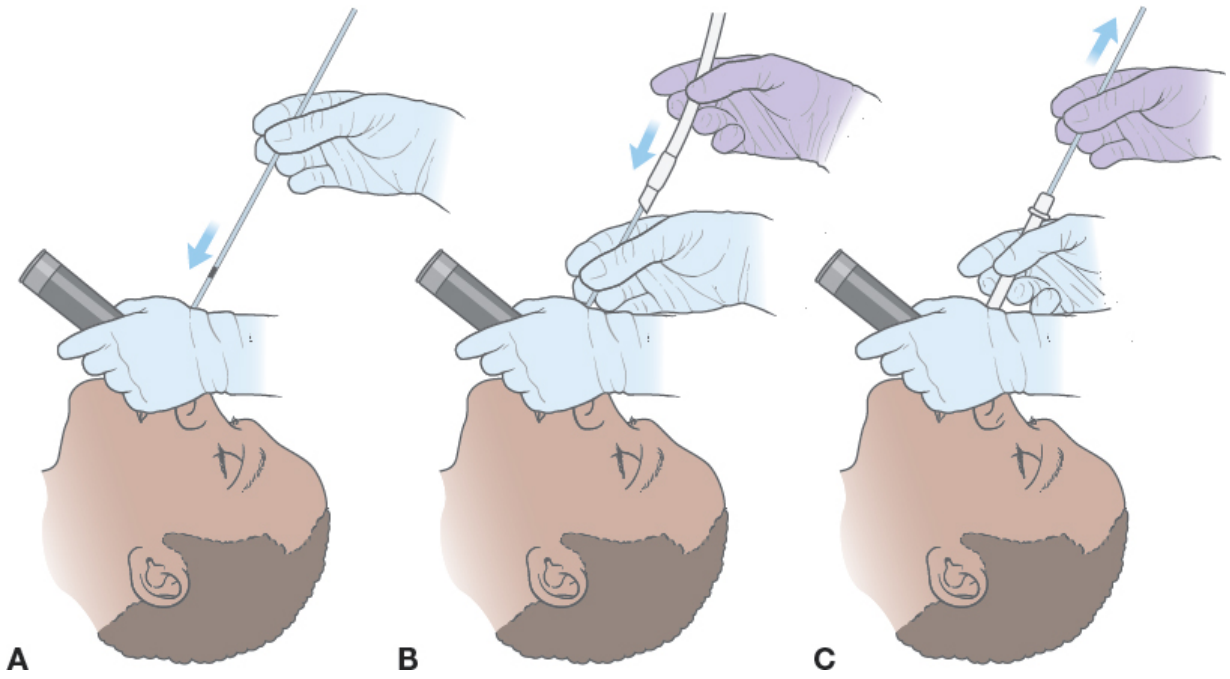

Figure 15.14. Bougie intubation technique. The bougie (preshaped to the intubator's liking) is placed into the intubator's right hand after the best glottic view has been obtained. The intubator places the bougie into the trachea until a hard stop is felt. The assistant then treads the endotracheal tube (ETT) over the bougie, and the intubator pushes it into the trachea to the proper depth and stabilizes it (rotating it 90° counterclockwise just before the tip passes through the vocal cords; see Fig. 15.15). The assistant then removes the bougie. The intubator maintains visualization of the glottis throughout the entire procedure.

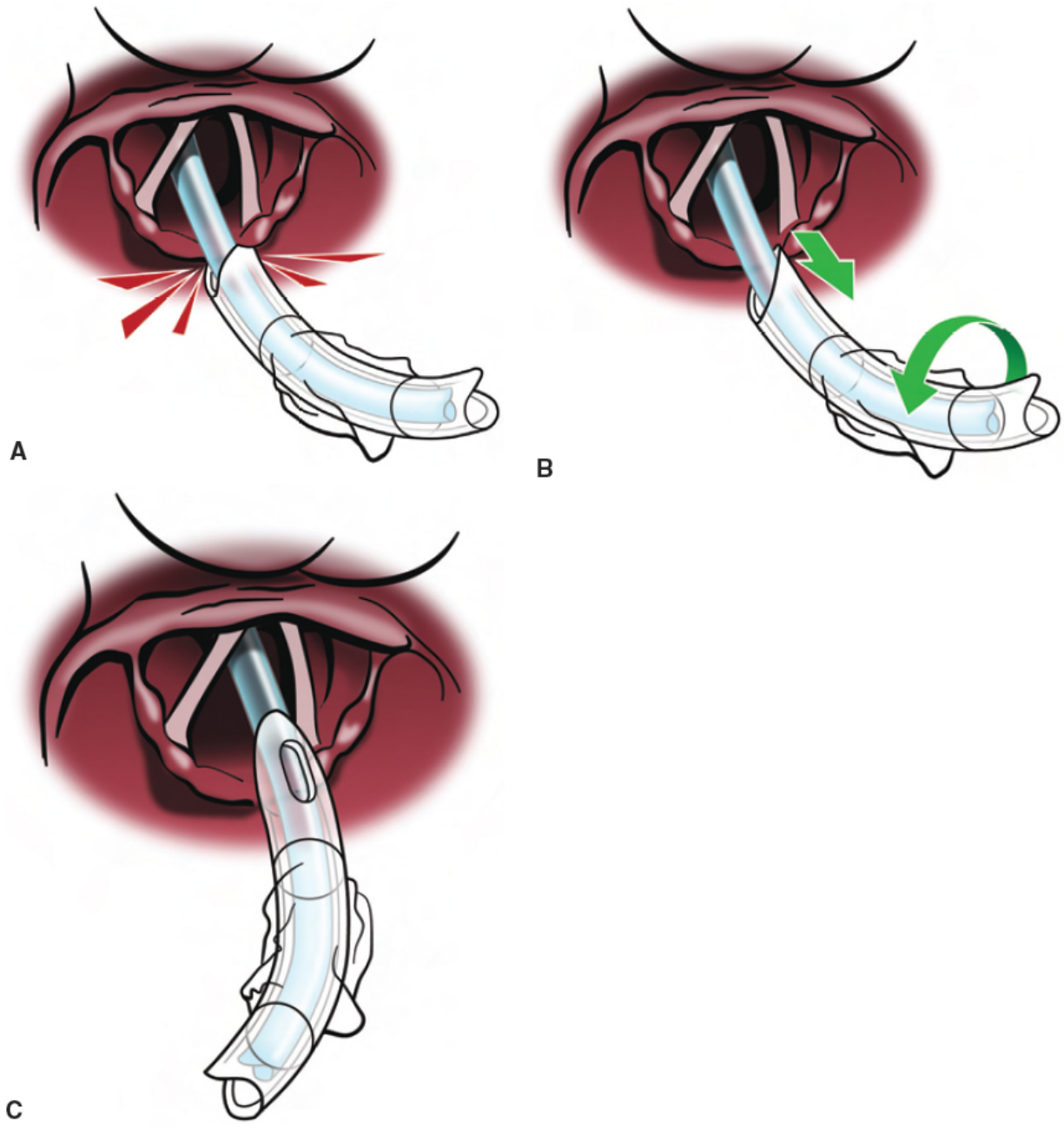

Figure 15.15. Counterclockwise rotation of the endotracheal tube (ETT) during insertion over the bougie. A: The tip of the ETT is hung up on the glottis, which is common. B: The ETT is withdrawn 1 to 2 cm and then rotated 90° counterclockwise. C: With the bevel facing posteriorly, the ETT passes smoothly through the glottis.

FAILED LARYNGOSCOPY AND INTUBATION

When tracheal intubation is unsuccessful, the patient should generally be reoxygenated with BMV and high-flow oxygen when the saturations fall to

93% or less. During this time, the laryngoscopist should systematically analyze the likely causes of failure (**Table 15.1**). It makes little sense to attempt a second laryngoscopy without changing some aspect of the technique to improve chances for success. The following questions should be addressed:

TABLE 15.1 Errors Associated With Failed Laryngoscopy

Rushed/frantic laryngoscopy	If the patient is rapidly desaturating, do not try to intubate hurriedly. Use BMV to improve oxygenation, and then perform relaxed, methodical laryngoscopy.
Laryngoscopy without a plan	Do not just insert the blade and hope that the vocal cords appear. This will usually result in advancing the blade too deeply, missing anatomic landmarks. Use a methodical approach with progressive visualization of anatomic structures—follow the tongue to the epiglottis and then the epiglottis to the vocal cords.
Poor tongue control	No tongue should be visible on the right side of the blade during properly performed laryngoscopy. This will prevent good visualization of the glottis and passage of the ETT.
Poor ergonomics	Holding the laryngoscope incorrectly, bending over in an awkward position, resting your elbow on the patient or the bed, and positioning your eyes too close to the procedure are recipes for failure.

- Is the patient in the best position for laryngoscopy and intubation? If the patient was placed in the sniffing position initially and the larynx still appears quite anterior, reducing the degree of head extension could be helpful. It may occasionally help to elevate and flex the patient's head and neck with the laryngoscopist's free right hand while performing laryngoscopy to create a better view of a true anterior airway.
- Would a different blade provide a better view? If the initial attempt at laryngoscopy was done with a curved blade, it may be advisable to change to a straight blade, and vice versa. Alternatively, a different size blade of either type might be helpful.
- Is the patient adequately relaxed? Appropriate neuromuscular blockade can improve the view of laryngoscopy one full Cormack-Lehane grade. Laryngoscopy may have been attempted too soon after

administering a neuromuscular blocker, or an inadequate dose may have been administered. If succinylcholine was used and the total time of paralysis has been such that the effect of succinylcholine is dissipating, then administration of a second full paralyzing dose of succinylcholine is advisable. Atropine should be available to treat bradycardia that occasionally accompanies repeat dosing of succinylcholine.

- Would external laryngeal manipulation be helpful? Manipulation of the thyroid cartilage by the laryngoscopist or the assistant, as described previously, often improves the laryngeal view by one full Cormack-Lehane grade.
- Is a more experienced laryngoscopist available? If so, a call for help may be in order.
- If DL has been maximized, is a VL available? If so, recourse to VL should be considered early.

CONFIRMING INTUBATION OF THE TRACHEA

Once the ETT has been placed, it is imperative to confirm that it is in the trachea. $ETCO_2$ detection has long been considered the gold standard for tracheal tube confirmation. Both qualitative colorimetric detectors and quantitative capnography are nearly 100% accurate for confirming tracheal tube placement in patients who are not in cardiac arrest. In the setting of cardiac arrest, continuous waveform capnography is the most reliable method for confirming correct ETT placement. Colorimetric $ETCO_2$ detectors quickly change from purple ("poor") to yellow ("yes") when $ETCO_2$ is detected. This color change should occur within a few breaths after tracheal intubation, and a lack of color change indicates an esophageal intubation. Uncommonly, CO_2 from the stomach can create a color change to yellow, but this will revert to purple within six breaths. With proper tracheal intubation, the color should continue to change from purple to yellow with each breath. A color change to tan, rather than bright yellow, may indicate esophageal or supraglottic misplacement. In cardiac arrest, colorimetric detectors have muted value because the $ETCO_2$ may be less than the detectable limit for color change (usually 5% CO_2 in exhaled gas),

so capnography should preferentially be used. Suction esophageal detection devices exist, but these are rarely, if ever, used in emergency medicine. When proper placement is in doubt and color change is not clear, the intubator should assume the ETT is not in the trachea and undertake efforts to either confirm placement or extubate and reintubate. When waveform capnography is used, tracheal intubation is confirmed by visualization of a square waveform that persists for at least six breaths. Absence of a waveform confirms esophageal placement. In cardiac arrest, the presence of a waveform confirms endotracheal intubation, whereas the lack of a waveform is indeterminate, requiring use of an alternative detection method.

When using a device that allows both DL and VL, confirmation of tracheal placement is immediate. VL or bronchoscopic confirmation of tracheal intubation is helpful when other methods of confirmation are confusing, especially in cardiac arrest. Auscultation is important for detecting mainstem intubation and pulmonary pathology but is unreliable for confirming tracheal tube placement. Chest x-rays should not be used to differentiate whether the ETT is in the trachea or the esophagus but only to assess proper ETT depth and to evaluate for mainstem intubation. Fogging (condensation) of the ETT is a *completely unreliable* method of confirming tracheal intubation and should not be used.

EVIDENCE

Does DL still have a role in the era of VL?

Most experts agree, and the evidence strongly suggests that VL is superior to DL in virtually all airway scenarios. Most also agree that it is optimal for emergency care providers to be skilled at both VL and DL. In addition, there is evidence that SG-VL blades are superior to hyperangulated VL (HA-VL) blades for tube placement but not for viusualization.[1] In addition, SG-VL permits simultaneous DL and VL, which allows the operator to use VL for anatomically difficult airways and DL in the event that the VL camera becomes obstructed by blood, vomitus, or secretions. In a randomized ED SG-VL (Storz C-MAC) study of bougie first versus ETT stylet, the bougie group had the highest first-pass intubation success (98%).[2] Although the Storz C-MAC was utilized, it was the operator’s choice

whether to perform DL or VL, and 58% of the patients in the bougie group were intubated under direct vision [the operator not viewing the Concurrent Media Access Control (CMAC) monitor at any point during the procedure], which might have contributed to the very high first-pass success rate. Indeed, Macintosh-shaped VL devices allow the possibility of DL and VL during the same intubation attempt, which may be important for optimizing first-pass success, especially in the unpredictable setting of emergency airway management. DL is unlikely to disappear completely from emergency medicine, although its role in airway management is becoming less relevant year after year.

What is the safest and most efficient way to teach DL in the emergency setting?

A minimum of 50 intubations are needed to become proficient at DL in the elective setting.[3] It is more difficult to teach and learn DL in the emergency setting, and the number of intubations needed to gain proficiency in difficult emergency airways is likely much higher than 50. Teaching DL with a traditional laryngoscope in the emergency setting can be challenging for both trainees and the instructors given that only one person can view the airway directly.[4] The rate of complications increases dramatically when there are multiple intubation attempts, so the goal should be first-attempt success.[5,6] VL has been shown to increase intubation success even in difficult airways; however, hyperangulated VL devices do not recreate DL mechanics.[7-9] Because VL is a technology that is susceptible to electrical and digital malfunction, DL remains an important skill that trainees should attempt to master. Today, several devices allow simultaneous DL and VL for both adult and pediatric patients.[10-12] There is subjective and objective evidence that these devices shorten the learning curve for DL.[10-13] In a small randomized trial of 198 patients intubated with either a standard geometry blade C-MAC or a DL, first-attempt success was higher with VL (92% vs 86%), although the small sample size kept this from being statistically significant.[14] Eight patients (8%) failed DL intubation on the first attempt, and all were successfully intubated using VL on the second attempt. Interestingly, the residents involved in this study learned DL using the C-MAC, and this is the first ED-based study demonstrating the effectiveness of learning and performing DL with a Macintosh-shaped VL device.

What is optimal head and neck positioning for DL?

Cormack and Lehane devised the most widely accepted system of categorizing the view of the larynx achieved with an orally placed laryngoscope.[15] The sniffing position (head extension and neck flexion) has been widely accepted as the optimum position for orotracheal intubation. However, there is conflicting evidence that increased head elevation (increased neck flexion) or just simple extension (head extension and neck extension) may be better than the sniffing position.[16,17] Although the question of optimal head positioning remains, it is likely that it will vary from patient to patient. This highlights the importance of a two-handed technique for intubation, allowing for individualized adjustments during laryngoscopy. Morbidly obese patients should be placed in a "ramped" position, with significant elevation of the shoulders, neck, and head such that a horizontal line can be drawn from the tragus of the ear to the sternal notch.[18-20]

Does external laryngeal manipulation and mandibular advancement improve DL?

It has been clearly shown that external laryngeal manipulation, one example of which is BURP, improves laryngeal view by one full grade, on average. In addition, one recent study demonstrated the importance of operator-directed laryngeal manipulation (as opposed to assistant-directed manipulation) in maximizing visualization of the glottic structures.[21] The importance of laryngoscopy being a bimanual technique is emphasized regardless of the direction in which the thyroid cartilage is displaced. In addition, one OR-based study showed that mandibular elevation (a jaw thrust) in addition to BURP improved the glottic view during DL by inexperienced laryngoscopists.[22]

Is a bougie truly helpful?

The literature clearly supports the use of a bougie to enhance success rates of intubation, particularly with grade 3 views.[23-26] In addition, a large randomized trial in the ED setting showed that using the bougie for every intubation attempt improved first-pass intubation success from 87% to 98%.[2] In the study, a Storz CMAC was used, although the operator could

choose to intubate under direct or video vision. When using a bougie, it is important to continue laryngoscopy while the ETT is advanced over the bougie and to rotate the ETT 90° counterclockwise as it passes through the larynx. Also, it may help to release cricoid pressure as the ETT is passed over the bougie.[27]

Does it matter which laryngoscope blade I use?

It is generally believed that one's choice of a laryngoscope blade and the technique used to facilitate intubation is best guided by personal choice and experience.[28,29] The literature suggests that straight blades improve laryngoscopic view (increased exposure of the vocal cords), whereas curved blades provide better intubating conditions (continuous visualization of the vocal cords during ETT passage).[28]

What are the best methods for confirming correct ETT placement?

No confirmation method is perfect, so providers should always use a combination of clinical assessment and detection devices. Continuous waveform capnography is recommended by the American Heart Association as the most reliable method for confirming and monitoring correct placement of an ETT.[30,31] Waveform capnographs provide a quantitative measure of $ETCO_2$ as well as a distinct repeating waveform that facilitates continuous monitoring of ETT position, even in most cases of cardiac arrest. An $ETCO_2$ waveform may be absent in cases of prolonged cardiac arrest or monitor malfunction, but good chest compressions and a viable patient will usually produce a detectable waveform. Colorimetric and nonwaveform exhaled CO_2 detectors are not as useful in cardiac arrest but are nearly 100% accurate for confirming correct ETT placement in patients who are not in cardiac arrest. Soft drinks in the stomach containing CO_2 may mimic the exhaled CO_2 from the lungs for a few breaths, the so-called Cola complication; this confounding result ought not to persist beyond six breaths.

There are several types of esophageal detector devices that detect esophageal intubation by creating negative pressure in the ETT, causing the walls of the esophagus to collapse around the tip of the ETT. Although these devices detect about 99% of esophageal intubations and are better in

cases of prolonged cardiac arrest, they are generally less accurate than $ETCO_2$ devices. In addition, these are rarely used during modern emergency airway management.

It would be reasonable to believe that visualization of the ETT entering the larynx is a reliable method of verifying correct ETT position, but it has been shown that additional confirmation methods are necessary, even when experienced providers place the ETT. Auscultation of the chest for breath sounds and of the epigastrium for absence of air entry into the stomach and observation of chest motion during ventilation are common but notoriously inaccurate methods of confirming correct ETT placement. Looking for condensation inside the ETT is a completely unreliable method for confirming correct placement. None of these techniques alone guarantee correct placement.

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CHAPTER 16

Video Laryngoscopy

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John C. Sakles

INTRODUCTION

In the past, direct laryngoscopy (DL) was the primary method of performing tracheal intubation in the emergency department (ED). When performing DL, the goal is to compress and lift the tissues of the upper airway out of the way so that a direct line of sight can be achieved between the intubator's eye and the laryngeal inlet. Chevalier Jackson, a pioneer in laryngoscopy, remarked in 1922 that, "The larynx can be directly exposed in any patient whose mouth can be opened, although the ease varies greatly with the type of patient." Because the ease of exposure does indeed vary greatly between patients, and because the grade of laryngeal view correlates highly with intubation success, video laryngoscopes were developed to allow intubation without achieving a direct line of sight between the mouth and the larynx.

Early use of flexible fiberoptics spurred the development of rigid fiberoptic laryngoscopes such as the Bullard laryngoscope, which was a rigid laryngoscope that incorporated a fiberoptic bundle and an eyepiece that allowed the intubator to see around the tongue. Although these fiberoptic laryngoscopes were cleverly designed, they required significant expertise to effectively use them. The inherent limitations of fiberoptics, including a small field of view, lens fogging, requirement of an ocular eyepiece, and easy contamination, restricted their widespread use. When video cameras were miniaturized enough to place them on the laryngoscope blade, new opportunities for laryngoscopy developed.

Dr John A. Pacey developed the first commercially available video laryngoscope, the GlideScope, which has been in clinical use since 2001. The video camera provided an indirect view of the airway and allowed intubation to be performed by viewing the video monitor. Since that time, numerous video laryngoscopes have been developed and are now in clinical practice. These devices differ considerably in their design, including differences in blade shape (standard geometry vs hyperangulated), tube delivery (freehand vs built-in channel guide), monitor placement (on the handle vs on a tower), and reusability (single use vs reusable), as well as other features. A common feature of each video laryngoscope, however, is the ability to achieve an indirect view of the laryngeal inlet and display the relevant anatomy on a video monitor. This allows intubation to be performed without having to move obstructing tissue out of the way. Additionally, the viewing angle is greatly increased over what is usually experienced with DL (10° with DL vs up to 60° with hyperangulated video laryngoscopy [VL]).

Video laryngoscopes are now used for many emergency intubations and current literature indicates that they are superior to direct laryngoscopes. This chapter will provide a general overview of the use of video laryngoscopes, followed by specific instructions for each class of video laryngoscope.

ADVANTAGES OF VIDEO LARYNGOSCOPY

VL has many advantages over DL:

- Obviates the need for a direct line of sight to airway
- Magnifies the view of the airway
- Requires less force to intubate
- Allows assistants to see and help with the procedure
- Allows instructors to supervise remotely
- Allows for recording of photos and videos that can be used for documentation and teaching

CLASSIFICATION OF VIDEO LARYNGOSCOPES

Video laryngoscopes can be fundamentally classified by two different blade shapes: standard geometry (Macintosh-style) or hyperangulated. Additionally, some systems also offer small Miller (straight) blades for use in pediatric intubation. Standard geometry video laryngoscopes have very similar geometry to standard Macintosh direct laryngoscopes but have a camera on the blade. Hyperangulated blades have an angle at the distal portion of the blade of about 60°; this angle was selected purely to optimize laryngeal visualization, with the consequence of making tube delivery more difficult compared to blade shapes with smaller distal angles. Hyperangulated blades can be further divided into those that have a tube guide channel and those that do not.

The two major video laryngoscope manufacturers, Karl Storz (C-MAC) and Verathon (GlideScope), and other smaller companies now have video laryngoscope systems that include both standard geometry and hyperangulated blade shapes. Because blade shape is no longer the defining difference between systems, this simplifies the decision of which system to purchase. **Figure 16.1** shows examples of standard geometry and hyperangulated blades. **Table 16.1** shows various types of commercially available video laryngoscopes and their characteristics.

Figure 16.1: Examples of Macintosh and hyperangulated video laryngoscope blades. Major video laryngoscope manufacturers produce blades in both Macintosh and hyperangulated shapes, with reusable and disposable options. Pictured here are blades from Storz C-MAC (top row) and GlideScope (bottom row). (Top row: ©2022 KARL STORZ Endoscopy-America, Inc.; Bottom row: copyright Verathon Inc.)

TABLE 16.1 Classification of Video Laryngoscopes

Video Laryngo Scope System	Macintosh-Style Blade Sizes, Adult	Hyperangulated Blade Sizes, Adult	Hyperangulated With Tube Channel Delivery	Pediatric Blade Sizes	Single Use Option	Reusable Blade Option	Power	Screen Location: on Handle or Corded External Monitor	Built-in Ability to Use Flexible Endoscope
C-MAC reusable	Mac 0, 2, 3, 4	D-blade and D-blade peds	No	Mac 0, 2 Miller 0, 1, 2	NA	Yes	Built-in rechargeable battery	Both are options	Both reusable and disposable endoscopes available

C-MAC disposable	Mac 3, 4	D-blade	No	Miller 0, 1	Yes	See row above	Built-in rechargeable battery	Both are options	Both reusable and disposable endoscopes available
Glidescope reusable	Mac T3, T4	LoPro T3, T4	No	LoPro T2	NA	Yes	Built-in rechargeable battery	Both are options	Disposable endoscope available
Glidescope disposable	DVM S3, S4 GVL 3, 4	LoPro S3, S4	No	LoPro S1, S2, S2.5. Miller S0, Miller S1	Yes	See row above	Built-in rechargeable battery	Both are options	Disposable endoscope available
McGrath MAC	Mac 3, 4	X blade size 3	No	Mac 1, 2	Yes	No	Replaceable proprietary battery	Handle	No
Venner AP Advance	Mac 3, 4	Difficult airway blade	Difficult airway blade with channel	Miller 1, 2	Yes	No	Requires both AA battery and built-in rechargeable battery	Handle	No
iView	Similar to Mac 4	No	No	None	Yes	No	Built-in battery—entire unit disposable	Handle	No
King Vision	No	Size 3	Size 3	Size 1, 2	Yes	No	Replaceable AAA batteries	Handle	No
Pentax AWS	No	No	Yes	Yes	Yes	No	Replaceable AA batteries	Handle	No
Airtraq*	No	No	Yes	Yes	Yes	No	Built-in battery—entire unit disposable	Handle	No
Vividtrac	No	No	Yes	Yes	Yes	No	No battery, powered through USB connection	Must use your own monitor (tablet, computer)	No
CoPilot VL	No	Size 3, 4	No	No	Yes	No	Built-in rechargeable battery	Corded connection to monitor	No
OneScope	Size 3, 4	Size 3, 4	No	Size 1, 2	Yes	No	Built-in rechargeable battery	Handle	No

The Airtraq uses mirrors to display images of airway structures and is not technically a video laryngoscope. However, its function is similar to other channeled video laryngoscopes.

WHEN TO USE VIDEO LARYNGOSCOPY INSTEAD OF DIRECT LARYNGOSCOPY

VL is becoming more affordable and ubiquitous, provides superior laryngeal views, and because multiple meta-analyses have demonstrated improved first-attempt success when VL is used, there is little reason to use a direct laryngoscope. The potential advantages of DL—that it is simpler, suffers from technical failure less often, is not soiled by body fluids, and has easier tube delivery—are reasons to maintain DL skills, but are not reasons to use a direct laryngoscope as a standard method. DL skills can be maintained with the use of a standard geometry

video laryngoscope, which allows the intubator to perform DL with recourse to a video screen should intubation prove difficult.

Technical failure and soiling of the camera occur rarely, and even when these difficulties are factored in, the success of VL is higher than DL. Soiling of the camera, an oft-cited concern for VL, is estimated to occur in just 1% of emergency intubations. Additionally, first-attempt success for both DL and VL are lower when body fluids are present in the mouth, with DL having significantly lower success rates.

Some advocate for using DL for straightforward airways, and VL for difficult airways. This is not convincing for two reasons. First, the difficulty of a patient's airway is not always known before laryngoscopy. Second, for a device to be useful in difficult airways, the operator must have skill with that device. Like nearly every procedure, an operator's skill improves with repetition. For a video laryngoscope to successfully intubate a patient with an anatomically difficult airway, the operator should have substantial practice with that particular device. This practice should not occur *solely* in difficult airways, because the incidence of a truly difficult airway is low enough that an operator might not gain sufficient practice.

DIFFERENCES IN TECHNIQUE FOR VIDEO LARYNGOSCOPY COMPARED TO DIRECT LARYNGOSCOPY

As VL provides a clearer view of the larynx but does not always provide a straight tube delivery path, the technique differs from DL. We will provide specific instructions for standard geometry VL and hyperangulated VL later in the chapter. Key differences in technique for VL compared to DL include:

- The tongue does not need to be fully displaced to achieve a good view of the airway. If the operator is looking at the screen during the intubation, the tongue does not obstruct the view. Thus, the blade can be placed down the midline of the tongue.
- Visualization of the airway is improved. Obtaining a good view is almost never a problem, even in the presence of body fluids—provided good technique is followed.
- Tube delivery can be more challenging. As the tongue is not being displaced as much as in DL, the operator must direct the tube around the curve to reach what is seen on the screen. Traversing this curve is typically the most challenging aspect of intubation using VL, especially when a hyperangulated blade is used.
- For hyperangulated blades, a special stylet should be used. When using a hyperangulated blade, the operator should use a rigid stylet that matches the curve of the blade. Otherwise, it can be very difficult to maneuver the tube around the curve.
- The camera can sometimes be soiled by body fluids. This occurs infrequently and can be avoided with good technique.
- The operator must, at key moments and in turn, look in the mouth and the screen during the course of intubation. This helps avoid injury to the tonsils and other oropharyngeal structures when advancing the blade and tube.

STANDARD GEOMETRY VIDEO LARYNGOSCOPES (MACINTOSH-STYLE)

Except for the addition of the camera on the blade, standard geometry video laryngoscopes are very similar to Macintosh direct laryngoscopes. For this reason, this type of video laryngoscope can be used for DL as well as VL. Because more traditional laryngoscopic mechanics are used, the trajectory from the mouth to the glottic opening is fairly straight and thus a rigid curved stylet is not required. The relatively straight path between the mouth and the larynx also eases tube insertion because it permits more direct insertion and usually avoids tube or bougie impingement on the anterior trachea. Because DL technique can be used and tube delivery is more straightforward with standard geometry video laryngoscopes, they are the preferred everyday laryngoscope for emergency intubation, especially for training programs.

Previously the C-MAC system (Karl Storz, Tuttlingen, Germany) was the main system that included a standard geometry video laryngoscope blade, whereas GlideScope (Verathon Inc, Bothell, WA) only offered hyperangulated blades. Presently, both these manufacturers and many other video laryngoscope manufacturers offer blades in both standard geometry and hyperangulated shapes. Thus, all institutions should have the ability to intubate with either blade shape.

Intubation With a Standard Geometry Video Laryngoscope

Steps to Obtaining a View of the Airway

1. Position the patient in an ear-to-sternal notch position, usually achieved by elevating the head, clinical circumstances permitting.
2. The blade is inserted in the midline of the tongue under direct vision and advanced incrementally down the tongue in small steps until the tip of the blade is seen on the video screen.
3. The intubator then advances the blade slowly and methodically, in small steps, down the tongue and searches for the epiglottis. Because the epiglottis begins where the tongue ends, finding the epiglottis is straightforward as long as the intubator remains in the midline of the tongue and advances the blade deliberately.
4. The blade tip is placed within the vallecula (best, **Fig. 16.2**) or under the epiglottis (alternative if a good laryngeal view is otherwise impossible) to provide visualization of the glottic inlet. The blade should be positioned in the deepest recess of the vallecula, and not too shallowly (on the tongue), or too deeply (on the epiglottis). This provides the best view.

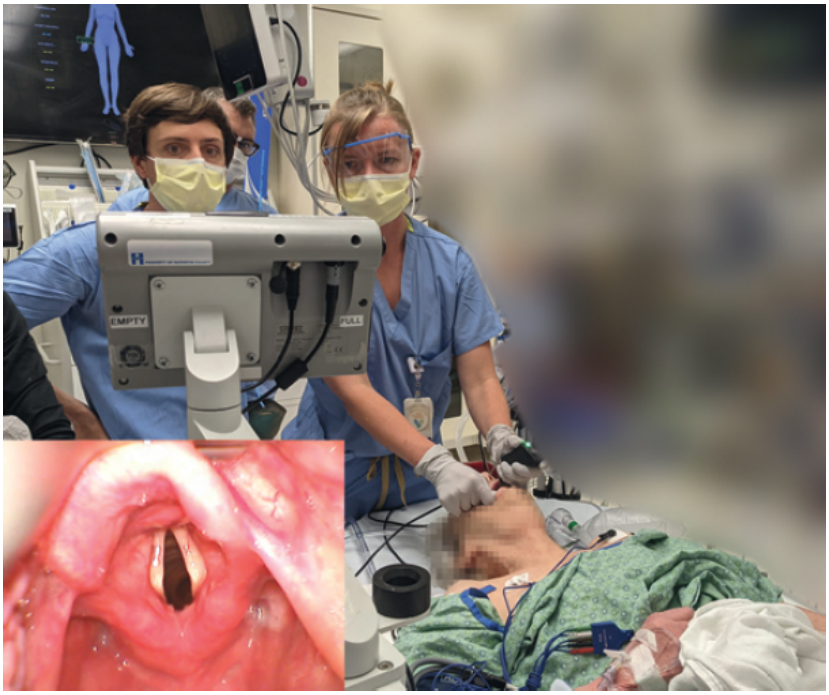

Figure 16.2: Macintosh video laryngoscope in clinical use. A Macintosh video laryngoscope (Storz C-MAC Macintosh 3) is being used to perform tracheal intubation in the emergency department. The operator is looking at the screen to optimize blade placement before tube delivery. Ideally, the bed height would be slightly higher, at or above the operator's umbilicus.

5. Within the vallecula, the target for the tip of the blade is a superficial mucosal fold in the midline of the vallecula that connects the tongue and the epiglottis (anatomically defined as the median glossoepiglottic fold and commonly called the midline vallecular fold, **Fig. 16.3**). Pushing the blade tip against this fold usually results in symmetric epiglottic lifting and is associated with better laryngeal views compared to not engaging the fold (which occurs when the blade is not in the midline of the vallecula). The intubator should manipulate the blade within the vallecula until the best possible view is obtained. This might include altering the direction of the force, moving the blade tip on or off the midline, or moving the blade tip to be more deep or shallow. Elevating the patient's head, performing external laryngeal manipulation, or performing a jaw thrust can also improve the view of the airway.

Figure 16.3: Proper Macintosh VL blade tip placement with emphasis of the midline vallecular fold. A: The intubator's view of the midline vallecular fold (indicated by the arrow), a midline mucosal fold that connects the base of the tongue to the epiglottis, as the blade approaches the vallecula. B: The blade begins to engage the fold, which helps indirectly lift the epiglottis. The intubator must place the tip of the blade deeply into the vallecula and ensure the tip is not too shallow (on the tongue) or too deep (on the epiglottis). C: The laryngeal view after the epiglottis is lifted indirectly.

If the patient has body fluids in the mouth, extra care must be taken to avoid soiling the camera lens. In these instances, ensure the blade remains pressed against the tongue while you suction visible fluids before incremental blade advancement. *Don't insert the blade into a puddle of fluids.* This also applies to hyperangulated blades.

Tube Delivery

The path from the mouth to the larynx is relatively straight and the tube is curved in a shape similar to that used for conventional DL.

1. If a tube + stylet is used, a straight-to-cuff shape should be created, with the tube being straight until the cuff, which is formed into a 25 to 35° angle (Fig. 15.10 in Chapter 15).
2. If a bougie is used, it should have a coudé tip. If no difficulty is anticipated, the bougie can be left straight. If a difficult airway is anticipated, the intubator can alternatively choose to bend the distal bougie up to a 60° angle beginning 15 to 20 cm from the tip. The exact bend needed will vary by patient. Do not unnecessarily bend or overbend the bougie.
3. The tube or bougie should be held far from the tip, near the adapter for the tube, and about 40 cm from the tip for the bougie.
4. Insert the tube or bougie from the extreme right corner of the mouth and then advance the tip to the glottis, keeping the tube or bougie below the line of sight while advancing toward the airway.
5. The tube or bougie is raised over the posterior cartilages just as it enters the larynx. If using a tube + stylet, advance the tube to the desired depth and remove the stylet.
6. If the bougie enters the larynx but cannot advance because it is impinging on the anterior trachea, slightly withdraw the bougie, rotate it at least 90° clockwise, and readvance. This particular problem is most often encountered when the blade is inserted too deeply, which tilts the larynx upward and increases the angle between the blade and trachea.
7. Once the bougie is in the trachea, the intubator leaves the blade in the vallecula and an assistant advances an endotracheal tube (ETT) over the bougie and into the intubator's hand. The tube is advanced and, just before entering the larynx, the tube is rotated 90° counterclockwise to position the bevel to avoid impinging on the right arytenoid cartilage (Fig. 15.15, in Chapter 15).

Summary

Standard geometry video laryngoscopes provide vast improvement over DL, while preserving the ability to train and perform DL. This laryngoscope type should be considered the default device for emergency intubation.

HYPERANGULATED VIDEO LARYNGOSCOPES

Hyperangulated video laryngoscopes are useful intubation devices that provide an excellent view of the airway in almost every instance. They can be used for routine intubations and in the setting of severe anatomic

distortion or failed airways. The hyperangulated curve means that the larynx is essentially *always* adequately visualized, but that tube delivery is more challenging. The intubator must view the screen to perform intubation—DL is not possible. Because the blade has a narrow profile and does not require direct visualization of the larynx through the mouth, it is useful when cervical mobility or mouth opening is limited.

Intubation With a Hyperangulated Video Laryngoscope

This section will be divided into three sections: performing laryngoscopy to gain a view of the airway, tube delivery with a non-channeled device (more common), and tube delivery with a channeled device (less common).

Steps to Obtaining a View of the Airway

1. Position the patient in an ear-to-sternal notch position, clinical circumstances permitting.
2. The handle is grasped with the left hand, in the same fashion as a conventional laryngoscope, and the tip of the laryngoscope blade is gently inserted into the mouth, in the midline, under direct vision.
3. Keep the handle in the midline as the blade enters further into the mouth, noting key midline structures like the uvula, as you advance the blade slowly. Do not sweep the tongue to the left—this makes it more difficult to identify landmarks.
4. As soon as the tip of the laryngoscope blade passes the teeth, the operator should view the video screen and use anatomic landmarks to advance toward the airway. Advance the blade incrementally down the tongue and past the uvula, with a slight elevating motion, until the epiglottis is seen.
5. Advance the blade into the vallecula and use gentle upward force to indirectly lift the epiglottis out of the way. The blade should ultimately be seated in the vallecula much in the same way that a Macintosh blade is used, with a key difference: the closest, best view of the airway complicates tube delivery and is not the ideal view (**Fig. 16.4**). The view that best facilitates easy tube delivery shows the airway somewhat off in the distance with the laryngeal opening on the top half of the screen (**Fig. 16.5**).

Figure 16.4: Hyperangulated video laryngoscope in clinical use with the blade inserted too far. A reusable GlideScope is being used to perform tracheal intubation in a blunt trauma patient in the emergency department. The front of the cervical collar has been removed and an assistant is maintaining in-line cervical stabilization. An excellent view of the laryngeal inlet has been achieved, but the operator has inserted the blade too far, causing elevation and tilting of the larynx, which will make tube delivery much more difficult.

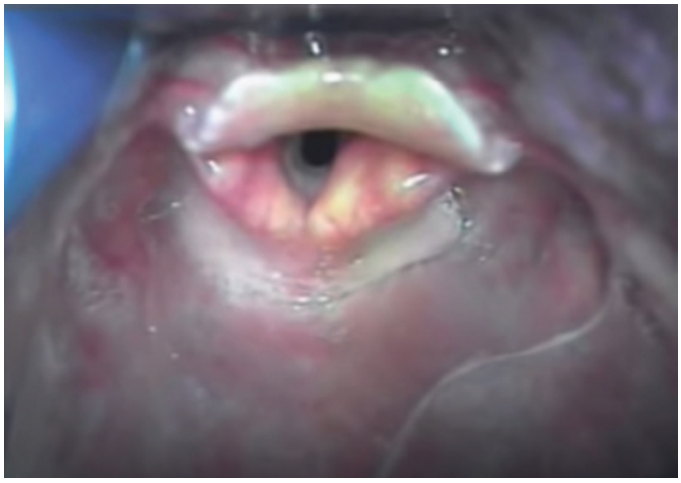

Figure 16.5: Hyperangulated video laryngoscope with better blade tip placement. In contrast to Figure 16.4, this image shows a hyperangulated video laryngoscope with the blade tip in a better location. The blade is seated in the vallecula, the airway opening is somewhat off in the distance and on the top half of the screen, and the larynx is not fully exposed. Compared to a full glottic view, this view makes tube delivery easier.

6. The intubator should be cautious not to place the blade too close to the glottic aperture. Although this may result in a larger, more obvious view of the target, it will make tube delivery and passage more challenging for two reasons:
    a. This tilts the laryngeal axis upward, which increases the angle between the laryngoscope blade and the trachea (ie, the tube will have to go upward more before traveling downward into the trachea—this exact problem can sometimes make tube delivery impossible).
    b. The size of the visualized field for tube delivery is reduced, which results in less room to maneuver the tube, demanding greater accuracy in tube placement.
7. If the glottic view is insufficient, often gently tilting the handle will fully expose it, in contrast to the lifting motion with a conventional laryngoscope. If the glottic aperture still cannot be exposed, the blade can be withdrawn slightly, placed under the epiglottis, and used like a Miller blade to physically displace the epiglottis up and out of the way. This motion, however, can tilt the larynx more sharply, making advancement of the tube into the trachea much more challenging.

Tube Delivery With a Hyperangulated Video Laryngoscope

Identifying and exposing the glottis is generally easy with a hyperangulated video laryngoscope. Because of the significant blade angle, however, advancing the tube toward the airway can be challenging. Negotiating the oropharynx and traversing the glottis around a hyperangulated blade can be technically difficult for two reasons. First, because hyperangulated blades have a steep angle (about 60°) with a distal upward (anterior) curve, and the trachea travels downward (posteriorly), the intubator must not only travel upward around the curve of the blade but also downward into the trachea (**Fig. 16.6**). Second, using the screen to navigate to the airway requires hand-eye coordination that differs from traditional DL.

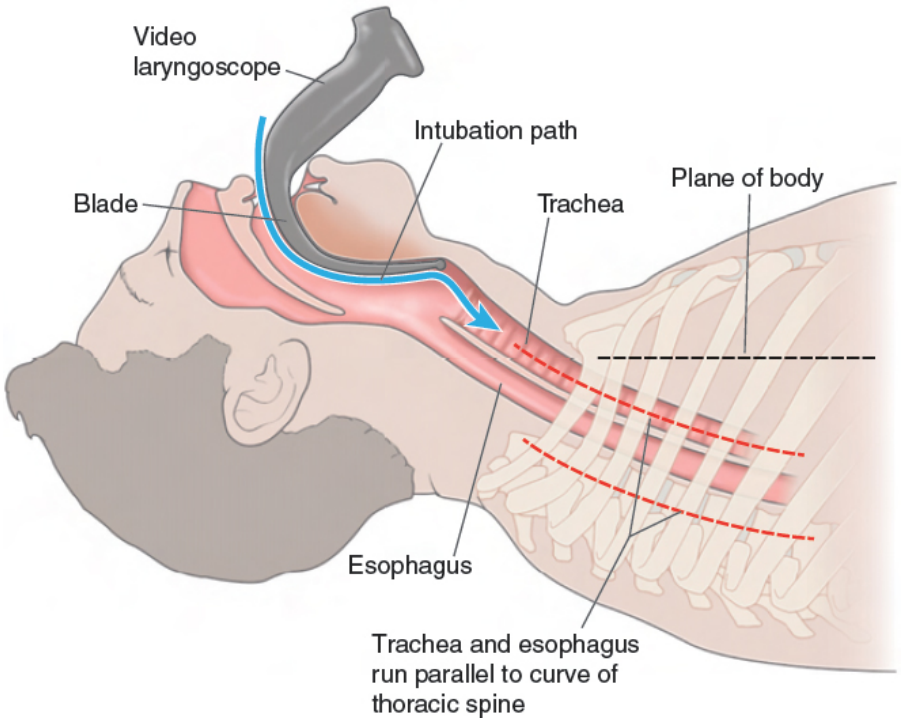

Figure 16.6: Posterior travel of the trachea. Orientation of the trachea. This figure, adapted from a figure published by renowned laryngoscopist Chevalier Jackson in 1915, shows that the opening of the trachea is relatively anterior, and that the entire structure is not perpendicular to the oral cavity but rather traverses posteriorly following the general direction of the thoracic spine. For the intubator using a video laryngoscope, this posterior trajectory of the trachea forces the tube to first travel around the curve of the blade and ending in an anterior (upward) orientation, before having to dive posteriorly (downward). Thus, tracheal orientation complicates tube delivery in video laryngoscopy.

The following steps describe ideal tube placement when using a hyperangulated video laryngoscope:

1. To achieve success with a hyperangulated video laryngoscope, the tube must be shaped to match the curve of the blade. Therefore, before the procedure, fit a rigid hyperangulated stylet into the tube. It is strongly recommended to lubricate the stylet and inside of the tube to make stylet removal easier.
2. After obtaining the view of the airway described above, the assistant hands you the tube + stylet.
3. Under direct vision, place the tip of the tube in the corner of the right side of the patient's mouth with the tube nearly parallel to the ground. Your hand will be at the 2- to 3-o'clock position. Advance the tube slightly and orient the tube more vertically alongside the blade.
4. Maintain direct visualization of the tube as it goes into the mouth and around the tongue until it is seen on the video screen. Perforations of the pharynx and hypopharynx have occurred with when tubes with rigid stylets are blindly inserted.
5. When the tube is well positioned, vertically oriented, and parallel to the blade handle, the operator looks at the screen and advances the tube along its curved axis to guide it into the laryngeal inlet, with the curvature heading anteriorly toward and into the opening of the airway.
6. Once the tube passes through the vocal cords and enters the trachea, the highly curved styletted tube will impinge on the anterior tracheal wall. At this point, the stylet must be partially withdrawn by the operator or assistant so the tip of the tube will straighten out. The operator's thumb can be used to withdraw the stylet a few centimeters back, which facilitates further advancement of the tube down the trachea.
7. If the tube continues to impinge on the anterior trachea, the blade should be withdrawn about 2 cm, causing the larynx to drop down, lessening the angle of approach and easing further advancement of the tube.
8. Rigid curved stylets have an extreme curve and are not malleable, and thus must be withdrawn from the tube in an arc over the patient's chest towards the feet. If a rigid curved stylet is pulled straight out like a conventional malleable stylet, the tube can accidentally be pulled out with it.

Tube Delivery With a Channeled Hyperangulated Video Laryngoscope

Some hyperangulated video or optical laryngoscopes (eg, King Vision with a channel, Airtraq, Pentax AWS) have a tube channel on the side of the blade which aids in tube delivery. This channel directs the tube around the curve of the blade and into the airway without the need for a stylet. Before inserting the device into the mouth, a well lubricated tube *without* a stylet should be placed into the channel as far as possible without obstructing the field of view.

These devices are longer than typical laryngoscopes and the chest wall of larger patients sometimes obstructs the top portion of the device during insertion. If this occurs, insert the device in the mouth while the whole unit is rotated 90° clockwise. After insertion, the device is rotated back to the patient's midline before advancement.

Obtaining a laryngeal view with these devices is similar to non-channeled devices, and the intubator should remember that the closest view is *not* the best view for tube delivery. The blade tip should be within the vallecula and should not lift the epiglottis directly. Before tube passage, the airway opening should be in the middle of the field of view.

Once the airway opening is visualized, the tube is advanced forward down the channel and into the airway. It is critical to rotate the ETT counterclockwise in the channel as it is advanced toward the airway. This will prevent the ETT from engaging and getting blocked by the right arytenoid. If the tube does not advance into the airway, withdraw the tube to its original position and manipulate the entire device to better align the tube trajectory with the airway opening. Although this is not difficult, it does require some practice before proficiency is attained.

Summary

Hyperangulated blades almost always provide full views of the laryngeal inlet, even in difficult airways. Because these full views are achieved by looking around a large curve, however, tube delivery is harder than with other devices, and a rigid stylet should always be used.

COMPLICATIONS OF VIDEO LARYNGOSCOPES

When used properly, video laryngoscopes are safe and effective devices. They have very similar risks of complications as direct laryngoscopes. The unique complications result from improper use. For example, if the intubator does not look at the patient while inserting the tube, the upper airway can be injured and some structures, including the soft palate or tonsils, can be perforated. Sometimes VL requires more time to intubate because of difficulty directing the tube to the airway. This can be remedied with practicing the correct technique, which maintains the blade in the proper position and depth, and use of an appropriately shaped stylet.

CONCLUSION

VL provides a superior view of the airway with less force than DL and should be considered a first-line technique for both routine and difficult airways. The video-assisted laryngoscopes outperform conventional laryngoscopes, especially in those patients with reduced mouth opening, cervical spine immobility, and head and facial trauma. Most users report that only a handful of intubations using a video laryngoscope are necessary before adoption of VL as a routine, everyday device. This has been confirmed by research demonstrating more rapid learning for VL than DL. Several models have disposable versions that greatly reduce cleaning time and the potential spread of infectious agents.

Video laryngoscopes are additionally helpful for confirmation of tube placement for patients in whom tube location is in question, visualization of upper airway obstructions and foreign material, and completion of difficult tube exchanges. Most important, video laryngoscopes allow real-time feedback for assistance and airway management education. The instructor can provide advice for successful intubation while allowing the operator to maintain control of the scope.

Direct laryngoscopes, for the purpose of endotracheal intubation, were introduced into clinical medicine approximately 100 years ago. Since then, little has changed in its application and performance. The development of video laryngoscopes over the past 20 years is a significant advancement in the field of laryngoscopy and intubation. Based on the current literature and expert opinion, it is clear that video laryngoscopes are safer and more effective tools than direct laryngoscopes for emergency intubations. They are associated with enhanced

laryngeal views, high first-pass success, low esophageal intubation rates, and low complication rates. All airway managers should be familiar with and comfortable using VL.

TIPS AND PEARLS

VL Use

- Always use a midline approach.
- Stay high in the mouth to avoid contamination from the posterior pharynx.
- Avoid advancing the blade too close to the larynx.
- When using a hyperangulated blade, use an appropriately curved, rigid stylet and remove the stylet slowly as the tube is being advanced down the trachea.

EVIDENCE

What is known about the role of video laryngoscopy in the ED?

The literature comparing VL to DL in the ED has consistently shown that VL is superior or equal to DL for emergency intubation. A recent analysis by Brown et al of 11 714 intubations from the National Emergency Airway Registry showed that unaided VL had higher success than DL augmented with bougie use, external laryngeal manipulation, or ramping.[1] A randomized trial by Driver et al found that the first-pass success was 92% for the C-MAC and 86% for DL, although this difference did not achieve statistical significance.[2] In an observational study by Sakles et al, the C-MAC was shown to have a higher first-pass success and overall success than the Macintosh direct laryngoscope.[3] In patients with difficult airway characteristics in the ED, Sakles et al found that use of the GlideScope or C-MAC resulted in a higher first-pass success than DL.[4] Sakles et al also found that in patients with a failed first intubation attempt in the ED, the C-MAC was superior to the direct laryngoscope in achieving successful intubation on the second attempt.[5] When used by emergency medicine residents, VL resulted in significantly fewer esophageal intubations than DL (1% vs 5%).[6] Sakles et al also found that the learning curve for VL was much better than that for DL, with emergency medicine residents increasing their first-pass success with GlideScope by 16% (from 74% to 90%) over a 3-year training period but only by 4% (69%-73%) with the DL.[7] A recently published Cochrane review found that standard geometry VLs reduced the likelihood of a failed intubation (RR 0.41) and hypoxemia (RR 0.72). This same review also found that hyperangulated VL reduced the likelihood of failed intubation (RR 0.51) and esophageal intubation (RR 0.39).[8] VL use is increasing over time. Results from the National Emergency Airway Registry, comprising more than 19 000 adult intubations from 2016 through 2019, showed that VL was used in approximately 60% of all ED intubation first attempts.[9]

What is known about the role of video laryngoscopes in the intensive care unit (ICU)?

Research into VL in the ICU is mixed, with most observational data suggesting that video laryngoscopes are superior to direct laryngoscopes for intubation of the critically ill.[10-14] However, many randomized trials, which typically exclude patients with difficult airways, have had negative results.[15,16] In a multicenter trial in France that enrolled 371 adult ICU patients,[16] success was not significantly different between VL (67.7%) and DL (70.3%). However, these success rates are fairly low in both groups and no stylets were used, limiting the generalizability to broader practice. Hypes et al have performed a large study on VL in the ICU and their propensity score analysis demonstrated that VL was associated with a higher first-pass success, lower incidence of oxygen desaturation, and a lower incidence of esophageal intubation.[13]

What is known about the role of video laryngoscopy in the prehospital setting?

There are limited data on VL use in the prehospital setting, but the existing literature is supportive. Wayne and McDonnell[17] compared the GlideScope to DL in an urban emergency medical services (EMS) system and found that paramedics were able to intubate successfully with fewer attempts when using the GlideScope. Jarvis et al performed a study comparing the King Vision to DL in their EMS system, finding increased first-attempt success when the King Vision was used compared to DL (74% vs 44%), as well as an increased overall success with the King Vision (92% vs 65%).[18] Boehringer et al found that when the C-MAC pocket monitor was incorporated

into their aeromedical flight program, first-pass success improved from 75% to 95% and overall success improved from 95% to 99%.[19] A systematic review and meta-analysis of data comparing video to DL demonstrated that those with less intubation experience gain more benefit from VL than those with extensive experience.[20]

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CHAPTER 17

Flexible Endoscopic Intubation

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Calvin A. Brown III

INTRODUCTION

Tracheal intubation over a flexible endoscope is an invaluable technique in airway management, particularly in patients for whom orotracheal intubation with rigid laryngoscopy is anticipated to be difficult or impossible. Endoscopic devices may be used for both diagnostic evaluation of the upper airway and tracheal intubation in a spontaneously breathing patient with a dangerous airway.

INDICATIONS AND CONTRAINDICATIONS

Indications for flexible endoscopic intubation (FEI) in emergency airway management are generally identified during the LEMON evaluation for the anatomically difficult airway (see Chapter 2) and include the following:

- Patients who fail the 3-3-2 rule (restricted mouth opening, small mandible, or high larynx) or exhibit a grade 4 Mallampati score.
- Inadequate oral access, recognized as a very limited interincisor distance, is a strong predictor of difficult or impossible orotracheal intubation via conventional means. Examples include wired mandible, trismus, temporomandibular joint disease, and tongue and oral floor space-occupying lesions (ie, angioedema, hematoma, oral infection).
- Distorted upper airway anatomy, particularly obstructing upper airway pathology, often precludes visualization by direct or video laryngoscopy and prevents appropriate seating of blind extraglottic devices. Examples include pharyngeal abscess, neck or posterior

oropharyngeal trauma or hematoma, angioedema and base of tongue or perilaryngeal tumor.

- Laryngeal trauma or suspected tracheal disruption. In these cases, intubation with continuous visualization without neuromuscular blockade is recommended. The endoscope meets this indication and is used to bridge the area of trauma in order to guide a thin-caliber tracheal tube beyond the area of injury without causing additional damage.
- Cervical spine immobility or deformity adds complexity to laryngoscopy, particularly if the airway is predicted to be difficult based on additional features. Rigid cervical collar and halo brace immobilization are the most common examples. Severe cervicothoracic kyphosis poses difficult positioning for most conventional and alternative airway interventions.
- Morbid obesity, especially when coupled with additional markers of difficult orotracheal intubation, may be preferably managed via FEI.

Contraindications to endoscopic intubation are relative and may include the following:

- Excessive blood and secretions in the upper airway have the potential to obscure the indirect view of FEI. Some experienced bronchoscopists transilluminate their way into the trachea, then verify tracheal position via the endoscope, but this is highly operator dependent and requires advanced flexible endoscopic skill.
- Endoscopy in the context of high-grade laryngeal or tracheal obstruction, as with foreign bodies, supraglottitis, or malignancy, may precipitate complete airway obstruction. In patients with high-grade supraglottic airway obstruction and impending complete airway closure, the delays and risks of precipitating laryngospasm or complete airway obstruction may argue against endoscopic intubation in favor of primary cricothyrotomy.
- Inadequate oxygenation by bag and mask (cannot intubate, cannot oxygenate scenario) does not permit endoscopic intubation because of the time constraints of this critical situation.

TECHNIQUE

Overview

Once FEI is recognized as the intended airway technique, the best route must be selected. Outside of disease-related issues, the nasotracheal approach is considered technically easier because the nose maintains the endotracheal tube (ETT) and endoscope in the midline, and the nasopharynx provides a panoramic and unobstructed view of the periglottic structures. The time required for topical anesthesia of the nose and use of smaller ETTs are significant drawbacks. The oral route typically accommodates a larger standard-sized ETT but requires more technical dexterity. Oral intubating airways are a great asset to maintain midline position and control the tongue. Although either technique can be used with minimal topical anesthesia during an immediate crisis, the oral route is better tolerated when time does not allow for thorough topicalization.

Patient Preparation

Although the emergency difficult or failed airway situation does not usually permit lengthy preparation, a methodical approach aims to provide psychological and pharmacologic patient preparation in a 10- to 15-minute window. Awake FEI generally includes the following patient preparation steps:

- Patient psychological preparation: Clear communication with explanation of the procedure improves cooperation with less need for procedural sedation.
- Antisialagogue administration: Glycopyrrolate 0.005 mg/kg IV, at least 10 to 20 minutes in advance of the procedure, reduces secretions to enhance visualization and improve efficacy of topically applied local anesthesia.
- Anesthetize the upper airway: Anesthesia improves patient tolerance during manipulation of the upper airway. FEI may be performed with limited anesthesia when patient condition mandates immediate intervention (see Chapter 24).
- Procedural sedation: Hypnosis should be used only if needed with careful titration to sustain airway patency and spontaneous ventilation.

Cooperative patients and those with critical airway compromise may not require or tolerate any sedation for FEI.

Scope Selection

Instrument selection for emergency airway endoscopy is important. Affordable and durable single-use disposable flexible endoscopes are available from a variety of manufacturers. Flexible endoscopy has several clinical uses, including:

- Tracheal intubation, both nasal and oral
- Diagnostic nasopharyngoscopy and laryngoscopy
- Oropharyngeal foreign body identification

The scope should be of sufficient caliber and stiffness to guide passage of an ETT through the curves of the airway without deformation or kinking and should resist being pulled from the trachea. Standard full-length (60 cm) adult diagnostic (5.0 mm) bronchoscopes are generally recommended for emergency department and critical care use given their availability and breadth of use. These scopes also have the benefit of a working channel for local anesthetic injection, suctioning, and pulmonary secretion aspiration.

Insufflation of oxygen through the working channel is now relatively contraindicated following reported cases of gastric insufflation and perforation. Patients requiring oxygen for support during the procedure can have face mask oxygen placed over the mouth or, if an oral approach is planned, either standard nasal tubing or high-flow nasal oxygen (HFNO) applied. Reusable endoscopes may have a light sourced from either a removable battery pack or a wall-powered light source. Newer single-use scopes use high-intensity light-emitting diode (LED) light sources integrated into the scope and powered through the view monitor (**Figs. 17.1** and **17.2**).

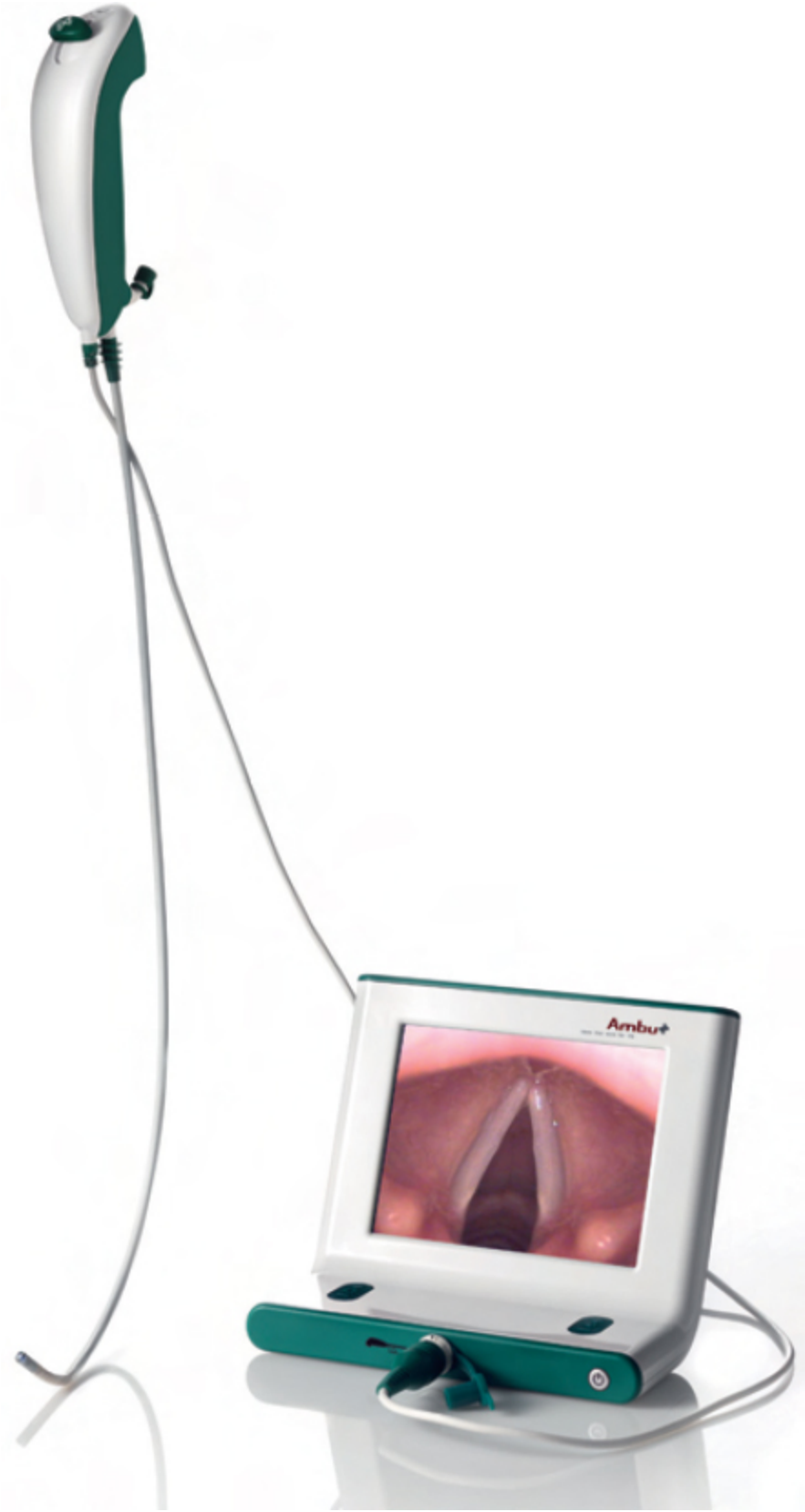

Figure 17.1: The Ambu aScope is a single-use, flexible intubating scope.

Figure 17.2: The Storz C-MAC FIVE S single-use, flexible intubating bronchoscope. (© KARL STORZ Endoscope. © 2022 KARL STORZ Endoscopy-America, Inc.)

Some endoscope manufacturers produce intubation-specific devices with enhanced stiffness that allows small scope caliber (3- to 4-mm tip diameter) to be used for diagnostic work or endoscopic intubation. Neonatal and pediatric endoscopes (2- to 3-mm tip diameter) are also available. It is important to note that 40-cm scopes for pediatric use or nasopharyngoscopy are not long enough to permit adult endoscopic intubation.

Care of the Instrument

Some general precautions are necessary to prevent damage to the delicate fiber-optic bundles in a scope, and similar precautions are prudent even with the less damage-prone video endoscopes:

- Do not drop the scope
- Use a bite-block to protect the scope. Oral intubation airway guides incorporate this feature (eg, Williams airway or Ovassapian airway) and are valuable aids to successful FEI (**Fig. 17.3**). The Rapid Oral

Tracheal Intubation Guidance System (ROTIGS) airway is a novel device design that guides the ETT and manages the tongue to avoid gagging (**Fig. 17.4**).

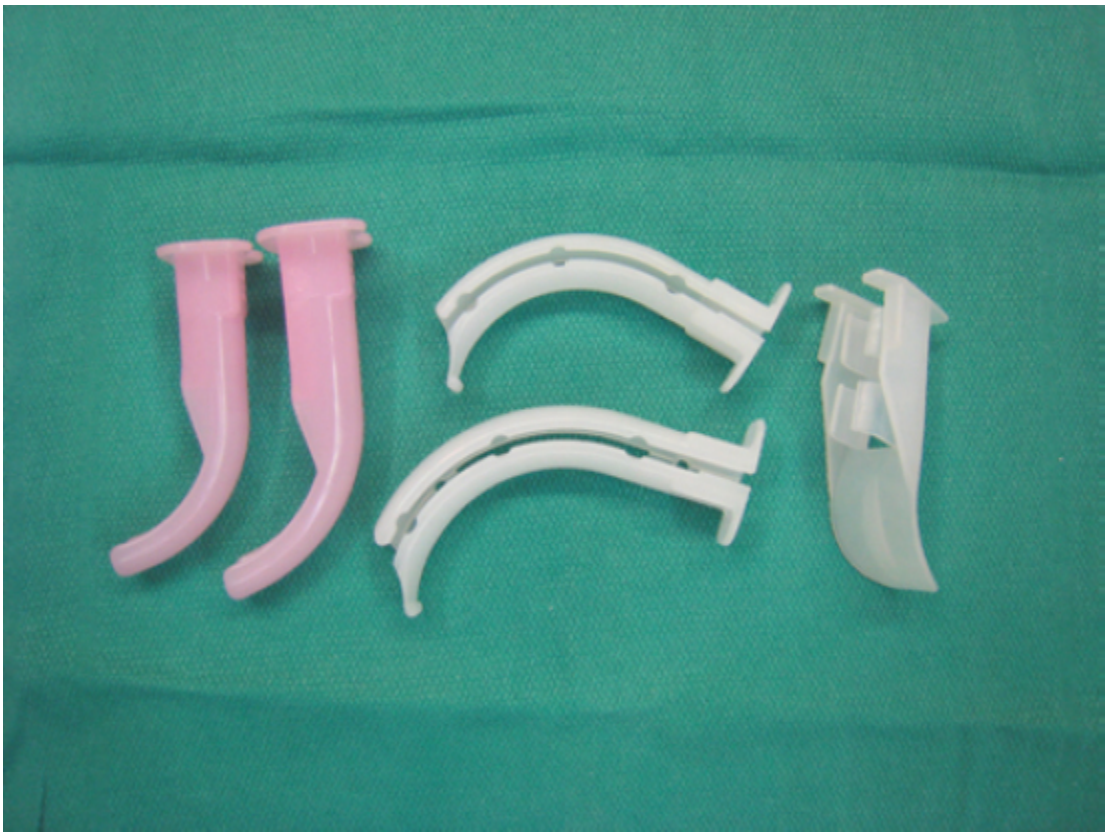

Figure 17.3: Three examples of oral intubation airways: Williams airway (left), Berman breakaway airway (center), and Ovassapian guide (right).

Figure 17.4: ROTIGS: Rapid Oral Tracheal Intubation Guidance System.

- Avoid acute bending or kinking the endoscope, especially when advancing the ETT over the scope into the trachea.
- If rotation of the ETT during intubation is necessary, rotate the ETT and the scope as a unit.
- Lubricate the ETT by applying local anesthetic agent or other water-soluble lubricant to facilitate removal of the scope after the ETT is placed. Lubricating the scope cord may make it slippery and difficult to manipulate.
- Do not flex the endoscope tip against undue resistance in order to manipulate the direction of the ETT or to retract tissue.
- For reusable flexible endoscopes, clean the device, including the working channel, immediately after use. Delayed flushing can lead to semisolid deposits and the development of infectious biofilms. The best routine is to suction 1 L of saline through the device immediately after use. Manufacturers and endoscopy units provide instructions for acceptable cleaning routines. Single-use scopes, such as the Ambu

aScope, Storz C-MAC FIVE S scope, and Verathon BFlex, are disconnected from the monitor after use and discarded in the appropriate biohazard containers.

Technique of FEI

The endoscope has two main components: a body (hand piece) housing the controls and port access and a long flexible cord, containing video or fiber-optic components (**Fig. 17.5**). Most flexible scopes now use video technology. Scope tip control is simple: tip flexion and extension along a single 270° arc is achieved with the thumb toggle on the body of the endoscope. The index finger activates the suction feature. Clockwise and counterclockwise long-axis endoscope rotation is achieved via wrist rotation. Flexing and extending the wrist moves the flexed endoscope tip left and right. The endoscope cord must be held straight to optimize this maneuver. Slack in the cord prevents wrist motion translation to the endoscope tip.

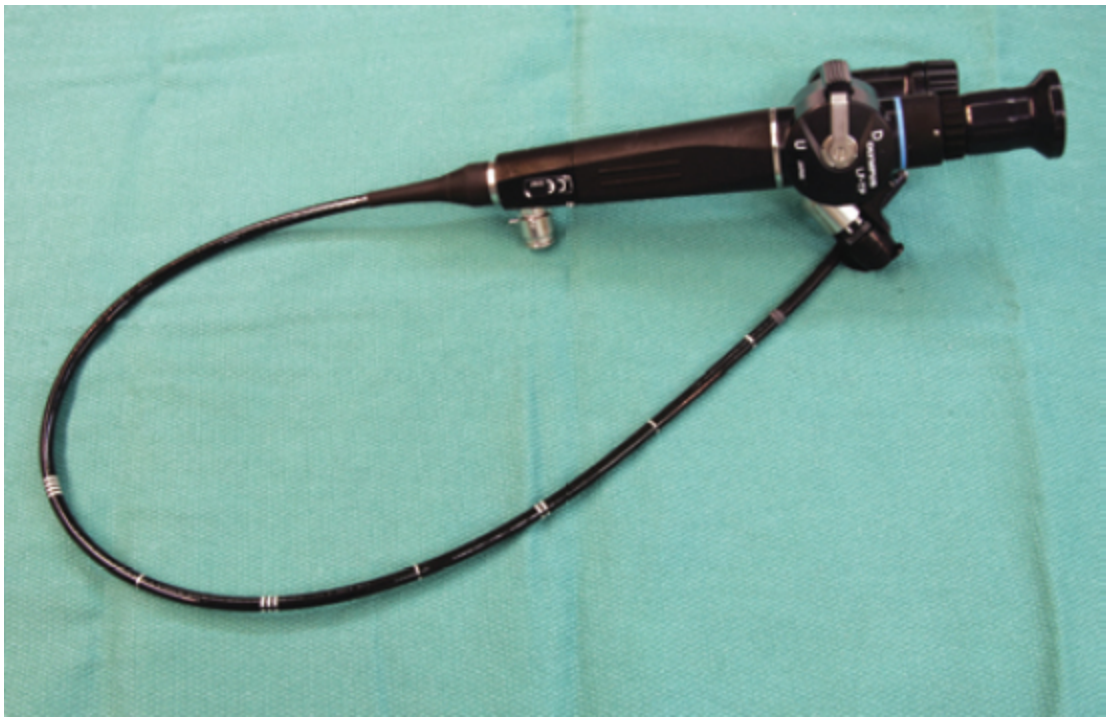

Figure 17.5: A standard adult flexible endoscopic intubating scope. Note the white marks denoting 10, 15, 20, 25, 30, 35, and 40 cm on the cord of the scope.

The dominant hand may be used to manage the endoscope body and controls or the distal cord at the interface with the ETT, whichever is more comfortable. Holding the endoscope body in the hand ipsilateral to the dominant eye facilitates keeping the cord straight when using a monocular eye piece. Some also advocate holding the body of the scope in the left hand to provide clearance of the light source cable and suction tubing, which exit on the left of the scope body.

Most current generation flexible endoscopes are video-capable systems that allow endoscopy view on an accompanying video screen.

Generally, visual targets should be maintained in the center of the field of view, especially as the scope is advanced. The hand holding the cord gently advances or retracts the scope. Move toward the target slowly, using small manipulations of the toggle and wrist rotation to maintain the glottic inlet in the center of the visual field. The operator's principal movements are hand and wrist manipulations of the scope. Hand-eye coordination needed for successful endoscopic intubation has been likened to the coordination of video game play.

Patient preparation for endoscopy depends on the time available. Generally, endoscopy supplies should be maintained in a state of readiness or available on a difficult airway cart:

1. Gather all equipment (preferably preassembled on a tray):
    a. Topical airway anesthesia supplies and equipment, including three 5- to 10-mL syringes loaded with 3 to 5 mL of 2% to 4% aqueous lidocaine to inject into the airway via the scope working port as needed. The remaining syringe should be filled with air flush to propel the anesthetic the length of the working port.
    b. Endoscope, ETTs, oral airways, bite blocks
    c. Tonsil suction
    d. Lubricant and antifog solution (the latter required only if using a scope with a remote light source)
    e. Backup airway management equipment as indicated in case of patient deterioration and need for rapid alternative intervention
2. Obtain an able and knowledgeable assistant, preferably one who is familiar with this procedure.

3. Prepare the patient:
    a. Discuss the procedure steps prior to and during the procedure.
    b. Antisialagogue, such as glycopyrrolate 0.005 mg/kg intramuscularly or intravenously, allowing sufficient time for this to work (minimum 10 minutes). This should be administered at first recognition of the procedure to allow time for effect.
    c. Vasoconstrict the nose with a topical agent if the nasal route is desired.
    d. Apply local, topical airway anesthesia (see Chapter 24).
    e. Maintain the patient in the position of comfort and optimize preoxygenation prior to procedure initiation.
    f. Apply sedation, for example, ketamine (0.25-0.5 mg/kg aliquots) IV, if needed. Titrate to the minimum level of sedation needed to complete the procedure.
4. Lubricate outside of the ETT. Lubricating the scope makes it slippery and difficult to manipulate.
5. Operator positioning is a matter of personal preference and patient tolerance. Most patients with respiratory distress or distorted upper airway anatomy need to be maintained in an upright sitting position. As such, stand up straight at the side of the bed facing the patient. Endoscopy can also be achieved from the head of the bed in the supine patient.
6. *Preinsert the ETT, with or without an airway device depending on technique* (see later).
7. Oral technique: Stay in the midline, stay in the midline, stay in the midline! *Mount the ETT within the oral intubating airway,* ensuring that the tip of the ETT is flush with the tip of the airway. Insert the airway and ETT into the mouth as a single unit approximately two-thirds of the way over the horizon of the tongue. Inserting the airway fully risks stimulating the patient and approximating the ETT tip too close to or beyond the glottis. An assistant must maintain the airway in the midline and avoid inserting the device too deeply. A conventional bite-block is a lesser alternative that only serves to protect the scope if an oral intubating airway is not available.

Alternatively, a 10-mL syringe can be transformed into a makeshift intubation guide by removing the plunger and cutting the tip end of the syringe, at the 1-mL mark, with trauma shears. Asking the patient to protrude the tongue or gentle tongue traction or jaw thrust by an assistant can help open the oropharynx to facilitate endoscopic view. If the patient is supine, placing the patient in the upright sitting position also makes the tongue less of an issue.

8. Nasal technique: Soften the ETT by placing it in warm water before inserting it. It may be helpful to dilate the chosen vasoconstricted and anesthetized nostril by gently and slowly inserting increasingly larger nasopharyngeal airways or a lubricated and gloved small finger into the nostril before inserting the ETT. This allows the operator to identify the largest and most patent nare. *Advance the lubricated ETT to the posterior nasopharynx (roughly 12 cm in the average-sized adult).*
9. *Insert the endoscope through the preinserted ETT* (see later). This delivers a clean endoscope proximate to the laryngeal target with minimal stimulation of the patient.
10. The assistant should aspirate oral secretions with tonsil suction as needed. Avoid nonessential endoscopic suctioning of the airway because secretions may soil and block the endoscope tip and view. The working channel of the scope may provide insufficient suction to clear secretions during the procedure, especially if they are thick or tenacious. If the tip becomes soiled or fogged and obscures clear vision, touch the tip gently against the mucosa to clear it.
11. Get your bearings. *Recognize that the endoscopic view is inverted when the procedure is performed while facing the patient.* On passing the scope through the preinserted ETT, slowly advance the scope while looking for recognizable structures. The base of the tongue and epiglottis are the most common first reference points.
12. Once the vocal cords are recognized, monitor opening and closing cadence with respiration. Ask the patient to breath slowly and deeply if they are cooperative. If time allows, inject 2 mL of 2% to 4% aqueous lidocaine through the working channel onto the larynx to obtund cough and closure reflexes. Position the scope in the center of

the glottis, and quickly advance the scope through the cords during inspiration.

13. If you are lost at any point, withdraw the scope until you identify a recognizable landmark.
14. Once through the vocal cords, advance the scope while confirming tracheal rings of the airway. Stop just above the carina to avoid invoking cough. The trachea is not well anesthetized, and patient stimulation and coughing should be anticipated.
15. Advance the ETT over the scope into the trachea, being careful not to kink the scope. A conventional laryngoscope may be used to straighten the angle of approach but is rarely required, except in the supine patient. Gentle rotation of the scope and ETT unit may be necessary if the ETT catches on the arytenoids. Special ETT tip designs may facilitate passage of the ETT through the cords (eg, Parker tube).
16. Confirm endotracheal intubation by visualizing the ETT tip within the trachea based on recognizable tracheal landmarks (eg, tracheal rings and carina). Stabilize the ETT to avoid dislodgement during scope withdrawal. Confirm end-tidal capnography immediately following endoscope removal.
17. Sedate the patient for ETT tolerance only after these intubation confirmation steps.

COMPLICATIONS

Complications with emergency FEI are uncommon and are most often related to respiratory decompensation because of the course of disease, sedative administration, or airway manipulation. A backup plan with appropriate alternative airway supplies should always be staged and ready prior to procedure initiation. Mucosal damage to the airway, including epistaxis, is usually mild, and damage to the vocal apparatus is possible but rare. Withdrawal of the endoscope prior to the ETT being advanced to the proper depth risks inadvertent esophageal intubation. Conversely, bronchus intubation can occur if the carina is misidentified or not appreciated. The endoscope may be damaged from biting, twisting, or kinking the cord.

EVIDENCE

How common is FEI in emergency department patients?

FEI is an uncommon procedure during emergency airway management. In the latest report from the National Emergency Airway Registry (NEAR), of more than 19,000 intubations from 25 participating centers, FEI was performed in just under 1% of encounters. Most were performed by emergency physicians and used for managing angioedema and nonangioedema airway obstruction.[1-3]

What is the learning curve for emergency FEI?

There are few data to establish the expected learning curve for FEI. Intubating over an endoscope, nasally and orally, is a well-established technique for managing difficult airways. It is recognized as an important skill in emergency medicine training but is not a skill required by the Accreditation Council for Graduate Medical Education (ACGME). We view FEI as a technical skill that requires initial training and then skill maintenance to maintain speed and proficiency. Manual dexterity in manipulating the endoscope is essential to performing rapid endoscopic intubation. The requisite psychomotor skills are developed with dedicated training and practice, and lack of training and experience constitute the most common cause of failed endoscopic intubation. A reasonable level of performance in bronchoscopic manipulation can be achieved with 2 to 3 hours of independent practice using an intubation model. We advise attending endoscopic intubation workshops with expert instruction and then practicing on intubation manikins or high-fidelity human patient simulators before attempting intubation in patients, especially those with difficult airways. Manufacturers of endoscopes often provide training videos, product support personnel, and manikins to support this endeavor.

The technique can also be learned in real-life situations by performing diagnostic nasopharyngoscopy, for indications such as severe sore throat, upper odynophagia, foreign body sensation, hoarseness, and other upper airway conditions. Gaining experience in routine cases is invaluable before attempting endoscopic intubation in a crisis. Patients requiring emergency intubation for nonhypoxemic respiratory failure in controlled conditions without anticipated difficult airway features are appropriate candidates for

endoscopic intubation, with the confidence of backup rapid sequence intubation.

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CHAPTER 18

Blind Intubation Techniques

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Darren A. Braude

BLIND NASOTRACHEAL INTUBATION

Whereas blind nasotracheal intubation (BNTI) was once a commonplace procedure for emergency intubation, it has now been relegated to a novelty in almost every setting in the developed world. With the advent of rapid sequence intubation (RSI) and technologies such as video laryngoscopes, flexible intubating endoscopes, extraglottic airways, and noninvasive positive-pressure ventilation (NIPPV), the need for performing BNTI has virtually vanished. In addition, intensive care units (ICUs) are generally unwilling to manage nasally intubated patients because the smaller tubes required for passage make ventilation and pulmonary toilet more difficult, and there is an increased risk of sinusitis.

The original indication for BNTI in emergency airway management was for the patient in whom intubation was deemed necessary but who still had intact airway protective reflexes, and medication-facilitated airway management (MFAM) was not available. Today, such patients would likely be managed with RSI. There was also a long-held belief that BNTI was preferable in the setting of confirmed or suspected cervical injury because of less perceived periprocedural cervical spine movement. This is no longer given any credence.

INDICATIONS AND CONTRAINDICATIONS

BNTI may still be considered in those situations where intubation is clearly indicated and where (1) RSI is not permitted by scope of practice, (2) RSI is

contraindicated because of predicted airway difficulty, or (3) the equipment or expertise for awake oral or visualized nasal intubation is not available. Unfortunately, success rates for BNTI never came close to those for RSI even when it was commonly performed; it is undoubtedly even lower now. Therefore, providers who are attempting BNTI must be ready to perform a surgical airway if unsuccessful.

BNTI is achieved by using some cue to recognize that the patient's spontaneous airflow is traveling through the endotracheal tube (ETT) after blind passage and that the procedure therefore cannot be attempted in the apneic patient or the chemically paralyzed patient. It is relatively contraindicated in combative patients; in those with anatomically disrupted or distorted airways (eg, neck hematoma, upper airway tumor); in the context of severe facial trauma with suspected basal skull fracture; in upper airway infection, obstruction, or abscess (eg, Ludwig angina, epiglottitis); and in the presence of coagulopathy. It is also a poor choice for patients with hypoxemic respiratory failure who cannot be adequately oxygenated during a protracted nasal intubation attempt.

TECHNIQUE

1. *Preoxygenate* the patient with 100% oxygen at flush flow rate.
2. *If the patient is awake, explain the procedure*. This is a crucial step that is often neglected. If the patient becomes combative during intubation, the attempt must cease because epistaxis, turbinate damage, or even pharyngeal perforation may ensue. A brief, reassuring explanation of the procedure, its necessity, and anticipated discomfort may avert this undesirable situation.
3. *Choose the nostril to be used*. Inspect the interior of the naris, with reference to the septum and turbinates. It may help to occlude each nostril in turn and listen to the flow of air through the orifices. If there appears to be no clear favorite, the right naris should be selected because it better facilitates passage of the tube, with the leading edge of the bevel laterally placed.
4. *Instill a topical vasoconstrictor* (eg, phenylephrine or oxymetazoline) spray into each nostril. This may reduce the risk of epistaxis and

make tube passage easier, although the evidence for this is limited. Atomization with a commercially available device may be the most desirable method of application. It may also be helpful to soak two or three cotton-tipped applicators in the vasoconstrictor solution and place them gently and fully into the naris until the tip touches the nasopharynx; this provides vasoconstriction in the area that is often most difficult to negotiate blindly with the ETT.

5. *Insert a nasal airway lubricated with 2% lidocaine jelly* into the selected naris. This helps to dilate the nasal passage and distribute the anesthesia. If there is ample time, some providers prefer to start with a smaller size and then sequentially replace these with larger diameter nasopharyngeal airways (NPAs) to "dilate up" to the size of the ETT to be used.
6. *Consider anesthesia of the posterior oropharynx* if time permits. The posterior cavity may be sprayed with 4% lidocaine or a similar spray; a commercially available "wand-style" atomization device may be the best choice for this application. Although not as effective, an alternative is to nebulize 3 mL of 4% aqueous lidocaine solution in a standard small-volume nebulizer (see Chapter 24).
7. *Select the appropriate ETT*. A specialized ETT such as the Endotrol (Covidien; Mansfield, MA) tube may be extremely helpful. These tubes have a "pulley-like" apparatus built into them to allow anterior deflection of the tip of the tube at the will of the operator (**Fig. 18.1A, B**). In general, the tube should be the largest one that will fit through the nostril without inducing significant trauma, or 6.0 to 6.5 mm in most adults. Test the ETT cuff for leaks in the usual manner. You may consider warming the tube as for a standard endoscopic nasal intubation only if you are using an Endotrol-type ETT. If you are using a standard ETT, warming may make it too floppy to deflect far enough anteriorly.

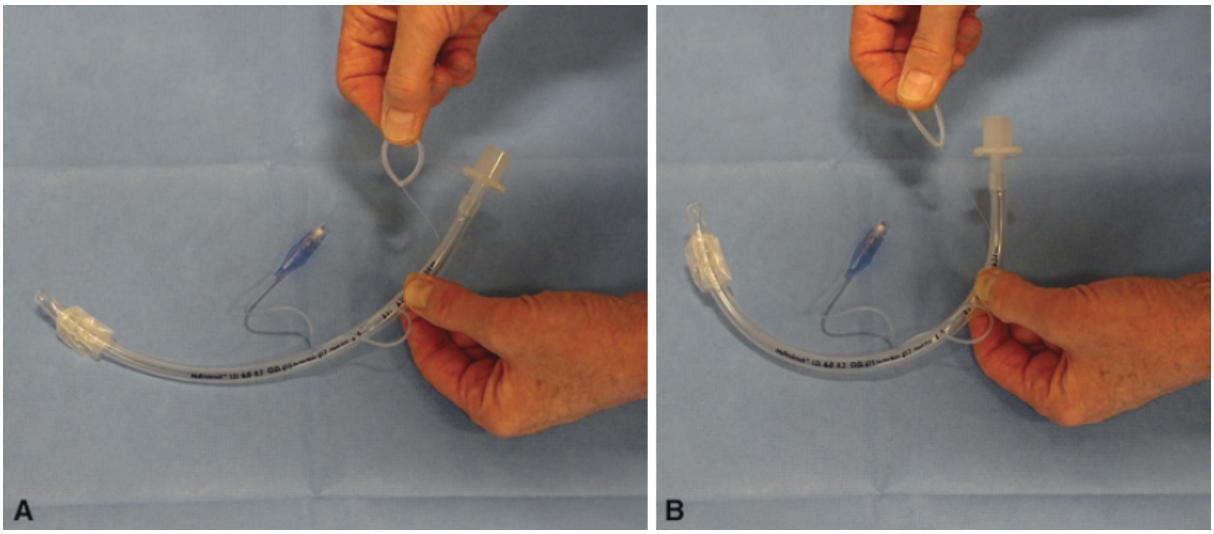

Figure 18.1: A: The Endotrol tube, without flexion applied. B: The Endotrol tube, with flexion applied.

8. *Prepare waveform capnography* (will be used for tube guidance; **Fig. 18.2**).

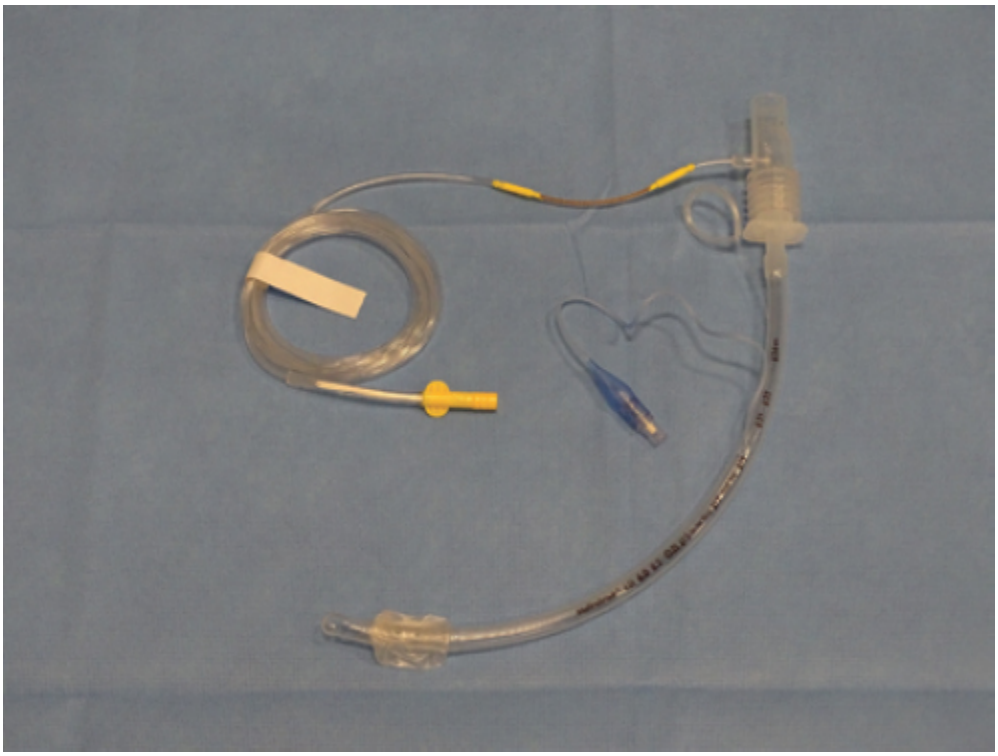

Figure 18.2: An Endotrol tube, with waveform capnography equipment attached.

9. *Lubricate the tube generously* using any appropriate ETT lubricant.

10. *Position the patient appropriately*. The awake patient will usually be seated, whereas the unconscious patient will usually be supine. In either situation, a sniffing or ramped position should be assumed unless contraindicated. Positioning the head as for oral intubation is worthwhile, if possible. The so-called “ear to sternal notch” position, with the neck flexed on the body and the head extended on the neck, optimizes the alignment of the mouth and pharynx (in the adult patient) with the vocal cords and trachea (see Chapter 15). A small, folded towel may be placed behind the adult patient’s occiput to help maintain this relationship. Care must be taken, however, to avoid overextension of the atlanto-occipital joint, because this can cause the tube to pass anteriorly to the epiglottis.
11. *Position yourself*. For a seated patient, the provider should position themselves where there is access and/or on whichever side they feel most comfortable to simultaneously manipulate the larynx, tube, and pulley mechanism. For the unconscious (but breathing) patient, it is often easiest to position yourself immediately above the patient’s head.
12. *Consider sedation*. Some patients may benefit from cautious intravenous administration of a sedative or dissociative agent prior to BNTI (see Chapter 24).
13. *Remove the NPA and consider final dilation*. The operator can consider inserting a gloved and lubricated little finger into the chosen nostril as deeply as possible to check for patency and to dilate the nostril to accept the tube.
14. *Insert the ETT*. Gently insert the ETT into the nostril, with the leading edge of the bevel lateral (ie, “bevel out” or “bevel away” from the septum) to theoretically minimize the risk of epistaxis. For consistency, the remainder of this discussion assumes a bevel out, right naris intubation, which orients the natural curve of the ETT with the natural curve of the airway without rotation. The major nasal airway is located below the inferior turbinate, and the placement of the ETT should follow the floor of the nose backward, with the tip directed slightly caudad to follow the gently downward sloping floor of the nasal cavity (see Chapter 7). This entire process should be

performed slowly and with meticulous care. Once the nasal portion of the airway is navigated, inciting epistaxis is unlikely. When the tip of the tube approaches the posterior nasopharynx, resistance will often be felt, particularly if the leading edge of the ETT enters the depression in the nasopharynx where the Eustachian tube enters. At this point, it is possible to penetrate the nasopharyngeal mucosa with the ETT and dissect submucosally if care is not taken. Often, rotating the proximal end of the ETT 90° toward the left nostril once this resistance is felt will facilitate "turning the corner" by orienting the leading edge of the ETT away from the depression. Once the oropharynx is successfully entered, restore the tube to the original orientation and proceed.

15. *Advance the tube with capnography detector attached*. Carefully observe for a normal square waveform morphology (**Fig. 18.3**). Loss of waveform indicates esophageal positioning. If using an Endotrol tube, the ring may be manipulated while monitoring for the best possible waveform. A Beck Airway Airflow Monitor (BAAM; Great Plains Ballistics; Donaldsonville, LA) has often been used as an adjunct to provide audible feedback—louder whistling indicates the larynx has been approached or entered, whereas cessation of whistling indicates esophageal passage (**Fig. 18.4**). Our preference is for capnographic guidance, although this has not been subjected to rigorous evaluation.

Figure 18.3: A waveform capnogram with normal morphology.

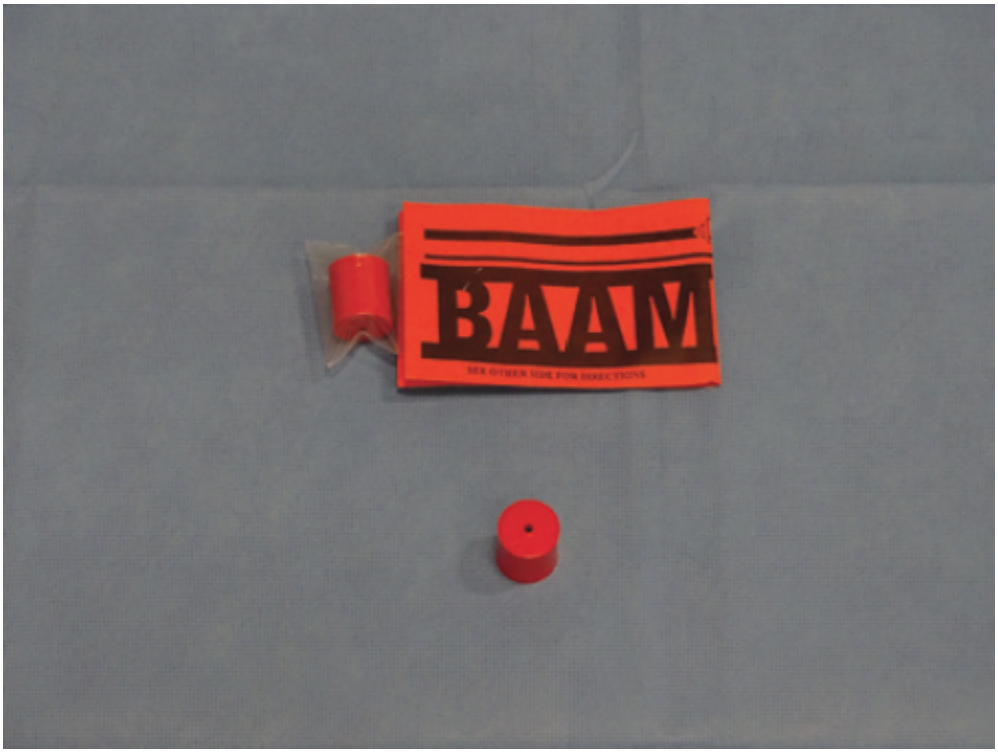

Figure 18.4: A BAAM device.

16. *Advance tube into larynx*. Monitor respirations and capnography, and advance the tube gently another 3 or 4 cm into the larynx during patient inspiration while applying laryngeal pressure with the hand not advancing the tube. The vocal cords abduct during inspiration and are most widely separated at this time.
17. *Determine whether the trachea has been entered*.
    a. If the trachea is entered, a series of long, wheezy coughs will usually emanate from the patient immediately, and the capnography waveform will be present.
    b. If the esophagus is entered, withdraw the tube until an $ETCO_2$ waveform is regained before attempting again. Consider repositioning the patient's head if not contraindicated, first with additional extension. Pay close attention to the amount of pressure applied to the Endotrol ring. Note that, at most, only 60% to 70% of BNTI will succeed on the first attempt. If the intubation is proving extremely difficult, consider the following troubleshooting options or abandon the attempt.
18. *Adjust tube depth*. Assess for an audible air leak, lost volume on the ventilator, and a square capnographic waveform—a tube in the hypopharynx will generate a waveform but will likely exhibit morphology that is "more peaked." Note that an appropriately positioned tube will be approximately **3 cm deeper** when measured at the nares than if it were measured at the lip after an oral intubation.
19. *Routine tube confirmation and postintubation management*.

TROUBLESHOOTING

- If available, the first best means of troubleshooting involves passage of a flexible endoscope to convert a blind procedure into a visualized procedure. The rest of this section will presume this technology is not available.
- Convert to an Endotrol tube if available and not used initially.
- If the tube has met with a "dead end," it may be anterior to the cords or abutted against the anterior wall of the trachea—it may be possible to

determine tube position by palpation—and slight withdrawal of the tube followed by slight flexion of the head may facilitate passage along with capnography guidance. If it is believed that the tube is off to the left or right, withdraw the tube, flex the head slightly if possible, and either twist the proximal end of the ETT or turn the head slightly in the direction to which the distal tip of the tube is believed to be off midline.

- Inflation of the cuff as the tube lies in the oropharynx may aid in alignment of the ETT with the glottic opening. The tube is then advanced until it meets with resistance at the cords, and then the cuff is deflated before being pushed through the cords during inspiration. Inflation of the cuff is felt to lift the end of the tube away from the esophagus and into alignment with the vocal cords. This should not be necessary when using an Endotrol tube.
- Change to a new tube, perhaps one that has a 0.5- to 1.0-mm smaller internal diameter. The tube often becomes warm and soft during the intubation attempt and is no longer capable of being appropriately manipulated.
- Grasp the tongue with a piece of gauze and pull it forward, or sit the patient up, if possible, to improve the angle at the back of the tongue.
- Abandon the attempt. Prolonged attempts are associated with hypoxemia and glottic edema caused by local trauma. Either condition can worsen the situation substantially. Repeated attempts are not significantly more successful than the first. In 10% to 20% of cases, BNTI will simply not be possible.

DIGITAL TRACHEAL INTUBATION

Digital tracheal intubation (DTI) is a blind tactile intubation technique in which the operator uses his or her fingers to direct an ETT into the larynx.

INDICATIONS AND CONTRAINDICATIONS

DTI has mostly been described or recommended for airway situations in which laryngoscopy equipment fails or is unavailable, such as the tactical and military environment, difficult patient positioning, or because of

extensive secretions obscuring visualization. Evidence for this procedure is limited primarily to cadaver and mannequin studies and case reports. Most such cases may also be managed with an extraglottic device (EGD), so it is rare that DTI would be the only or best option available. When performing DTI, the patient must be paralyzed or comatose, or at least sufficiently obtunded to prevent a biting injury to the operator.

TECHNIQUE

1. The right-handed operator stands on the patient's right side. Have an assistant use a gauze sponge to gently but firmly retract the tongue.
2. An ETT without a stylet should be tried first because this leaves the ETT tip most flexible and more easily deflected, digitally, into the larynx. If the operator's hand and fingers are short and unable to reach the glottic inlet, then a preshaped ETT with a standard malleable stylet can be used. Insert a stylet in the ETT and bend the ETT/stylet at a 90° angle just proximal to the cuff and place the ETT/stylet into the mouth. Alternatively, use of an endotracheal introducer (eg, bougie) has been described.
3. Slide the index and long fingers of the right-hand palm down along the tongue positioning the ETT/stylet on the palmar surface of the hand.
4. Identify the tip of the epiglottis with the tip of the long finger, and direct it anteriorly.
5. Use the index finger to gently direct the ETT/stylet or bougie into the glottic opening. If a bougie is used, tracheal positioning should be confirmed in the usual manner and then the ETT passed over it into the trachea.
6. Confirm ETT placement in the usual manner.

SUCCESS RATES AND COMPLICATIONS

Perhaps the most substantial limitation in performing this technique successfully is the length of the operator's fingers relative to the patient's oropharyngeal dimensions. Biting injuries or unintentional dental injuries to the hand with the risk of infectious disease transmission may occur. The technique has only infrequently been reported, and most authors agree that

some experience is needed to perform this technique efficiently and effectively. There are insufficient data to report a reliable expected success rate.

EVIDENCE

How often is BNTI performed in the emergency department (ED)?

Because RSI has become the method of choice for intubation of emergency patients, fewer physicians routinely perform BNTI. In a large multicenter registry of more than 17,500 adult ED intubations, Brown et al.[1] reported 162 nasal intubations, 99 utilizing a flexible endoscope; 63 (0.35%) were performed without a device (BNTI). Overall, first attempt success for nasal intubation was 65%.

How successful is BNTI when performed by prehospital providers?

In a meta-analysis by Hubble and colleagues, approximately 57,000 cases of prehospital airway management were examined. Overall, the BNTI success rate for nonphysician clinicians was 75.9%.[2]

Should waveform capnography be used to improve BNTI success?

To the authors' knowledge, there has not been a clinical trial comparing BNTI with, and without, use of this technology. Thus, recommendations for their use in BNTI represent expert opinion only.

References

1. Brown C III, Bair A, Pallin D, et al. Techniques, success, and adverse events of emergency department adult intubations. *Ann Emerg Med*. 2015;65:363-370.
2. Hubble MW, Brown L, Wilfong DA, et al. A meta-analysis of prehospital airway control techniques part I: orotracheal and nasotracheal intubation success rates. *Prehosp Emerg Care*. 2010;14(3):377-401.

CHAPTER 19

Emergency Surgical Airways

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INTRODUCTION

An emergency surgical airway is the final step of all modern airway algorithms, and it is imperative that all personnel who provide advanced emergency airway management be capable of performing this procedure expeditiously. For several reasons, the most challenging part of performing a surgical airway is making the decision to do it, rather than successfully completing the individual steps of the procedure. First, surgical airways are exceedingly rare, even by the busiest clinicians. Second, by definition, patients in need of an emergency surgical airway will have either precarious anatomy, precarious physiology, or both. Third, a case that ultimately necessitates a surgical airway is often viewed erroneously as a "failure." On this last point, it is imperative for the treating clinician to know, instead, that a properly performed surgical airway could be the only intervention separating their patient from life and death. Using the failed airway algorithm (see Chapter 5) allows providers to quickly recognize when a surgical airway is indicated and helps them to view it as viable option during emergency airway management. Using a system-wide approach with standard training and equipment as well as a standard algorithm will improve the performance of this rare and anxiety-provoking procedure.

Description and General Approach

An emergency surgical airway refers to establishing a definitive airway through the front of the neck (also referred to as "front of neck airway" or

"FONA"), either through the cricothyroid membrane (cricothyrotomy) or the trachea (tracheostomy). Given the complex dynamics described previously, it is imperative to select a technique that can be reliably completed by clinicians with variable levels of experience using readily available equipment. Because this is a rare life-saving procedure, it is also imperative to practice the technique periodically so that it can be effectively performed in a high-pressure setting. Finally, it is critical to understand that in the emergency setting surgical airways should be performed without attention paid to incisional bleeding until the airway is secured. Bleeding is inevitable, and visual confirmation of airway landmarks is not required because it is primarily a tactile procedure. Therefore, the operator must proceed without hesitation, knowing that the procedure will be performed *blindly*, relying on palpation of the relevant anatomic structures, with no expectation of actually seeing these structures.

Indications and Contraindications

Large, multicenter studies of emergency airway management, such as those described by the National Emergency Airway Registry (NEAR) reveal that the most common indication for emergency surgical airways is as a rescue technique when other less invasive methods fail. This approach is particularly relevant during *can't intubate, can't oxygenate* (CICO) scenarios (see Chapter 5). Less commonly, a surgical airway will be performed as the primary airway management method in patients for whom "standard" intubation is contraindicated or believed to be impossible. An example of this circumstance would be a patient with severe facial trauma and active bleeding in whom access through the mouth or nose would be too time consuming, hazardous, or impossible. Thus, cricothyrotomy should be viewed as a rescue technique in most circumstances and one that will be used, rarely, as the primary method of securing the airway.

In deciding to initiate surgical airway management, there are a few fundamental considerations:

1. Will accessing the cricothyroid membrane be *effective*? In other words, will an incision at the level of the cricothyroid membrane and introduction of an airway provide adequate ventilation and oxygenation? In most cases, the answer to this question will be *yes*

unless there is an obstructing lesion in the airway distal to the cricothyroid membrane. Performing a cricothyrotomy in this setting will not solve the problem and is a critical waste of time (see Chapter 37).

2. Will the patient's anatomy or pathologic process make cricothyrotomy *difficult* to perform? Placement of the initial skin incision is based on identifying the pertinent anatomy. If adiposity, masses, burns, trauma, or infection are likely to make this procedure difficult, the strategy should be adjusted accordingly. A mnemonic for difficult cricothyrotomy (SMART) is shown in **Box 19.1** and is discussed in Chapter 2.
3. Which *type* of invasive technique is best in the particular circumstances (ie, open surgical or percutaneous)? Although we strongly advocate for the open bougie-aided technique based on current available evidence (see *Evidence section*), a percutaneous approach may be preferred depending on the available equipment, patient characteristics, and provider skill. In obese patients, subcutaneous tissue may obscure landmarks, making needle localization difficult (see Chapter 43). For these patients, an open surgical cricothyrotomy is a better choice.

BOX 19.1 SMART Mnemonic for Difficult Cricothyrotomy

Surgery
Mass
Access/Anatomy
Radiation
Trauma

Contraindications to surgical airway management are few and with one exception are all relative. That one exception is young age. Children have a small, pliable, mobile larynx and cricoid cartilage, making cricothyrotomy extremely difficult and complication prone. For children 10 years of age or younger, unless they are teenage or adult size, avoid a standard open cricothyrotomy. Relative contraindications to cricothyrotomy include preexisting or acute laryngeal or tracheal pathology such as tumor, infections, abscess, hematoma, or upper airway trauma that would render

the procedure difficult or impossible. Although the presence of these anatomic barriers should prompt consideration of alternative techniques that might also result in a successful airway, in cases for which no alternative method is likely to be successful, cricothyrotomy should be performed.

TECHNIQUE

Anatomy and Landmarks

The cricothyroid membrane (CTM) is the most common anatomic site of access in the emergent surgical airway, regardless of the technique used. This approach has several advantages over the trachea in the emergent setting. The CTM is more superficial than the trachea and with less soft tissue between the membrane and the skin, and it is therefore easier to rapidly identify by palpation. There is also less surrounding tissue vascularity at this level compared with the tracheal and therefore a lower risk of significant arterial bleeding.

The CTM is identified by first locating the laryngeal prominence (notch) of the thyroid cartilage. Approximately one fingerbreadth below the laryngeal prominence, the membrane may be palpated in the midline of the anterior neck, as a soft depression between the inferior aspect of the thyroid cartilage above and the cricoid ring below. The relevant anatomy may be easier to appreciate in males because of the more prominent thyroid notch. We should emphasize that recent literature suggests that identification of the CTM by landmarks or palpation may be more difficult than previously assumed, especially in female and obese patients. In these patients, ultrasound is very accurate (and easy to learn) for identifying the CTM (see *Evidence section*). The CTM is disproportionately smaller in children because of a greater overlap of the thyroid cartilage over the cricoid cartilage, which is one reason cricothyrotomy is not recommended in children of age 10 years or younger.

It is important to recognize that the same anatomic or physiologic abnormalities (ie, trauma, morbid obesity, and congenital anomalies) that may necessitate a surgical airway may also hinder palpation of relevant landmarks. One way of estimating the location of the CTM is by placing four longitudinally oriented fingers on the neck, with the small finger in the sternal notch. The membrane is located approximately under the fourth

(index) finger, and this estimation can serve as a point at which the initial vertical skin incision is made. After this incision is performed, repalpation at the base of this incision is crucial to confirm the location of the CTM with more accuracy.

Equipment

A sample listing of recommended contents of a cricothyrotomy tray is shown in **Box 19.2**.

BOX 19.2 Recommended Contents of Cricothyrotomy Tray

Scalpel with no. 20 blade
Small blunt tracheal hook
Bougie
Standard 6.0 ETT
10 cc syringe

Technique

Several different cricothyrotomy methods have been described, including (i) percutaneous trocar methods, (ii) standard open cricothyrotomy, (iii) the No-Drop Technique, (iv) the Rapid-Four-Step Technique, (v) bougie-guided cricothyrotomy, and (vi) the Seldinger method.

Currently most experts recommend a simple open surgical technique using a scalpel, hook, bougie, and standard endotracheal tube (ETT). Regardless of which technique is used, they all have similar procedural steps.

These steps are as follows:

Step #1: Identify landmarks
Step #2: Immobilize the larynx
Step #3: Prepare the neck
Step #4: Incise the skin and soft tissue overlying the CTM
Step #5: Reidentify the membrane by direct palpation through the incision
Step #6: Stab the membrane
Step #7: Insert the tracheal hook (and grasp either above or below the membrane)
Step #8: Insert the bougie
Step #9: Advance the tube over the bougie
Step #10: Inflate the cuff and confirm tube placement

1. *Identify landmarks.* The patient is positioned supine (**Fig. 19.1**). The CTM is then identified with the dominant hand using the landmarks described previously. If the CTM cannot be clearly identifiable by palpation, use the four-finger technique or consider using ultrasound if time permits.

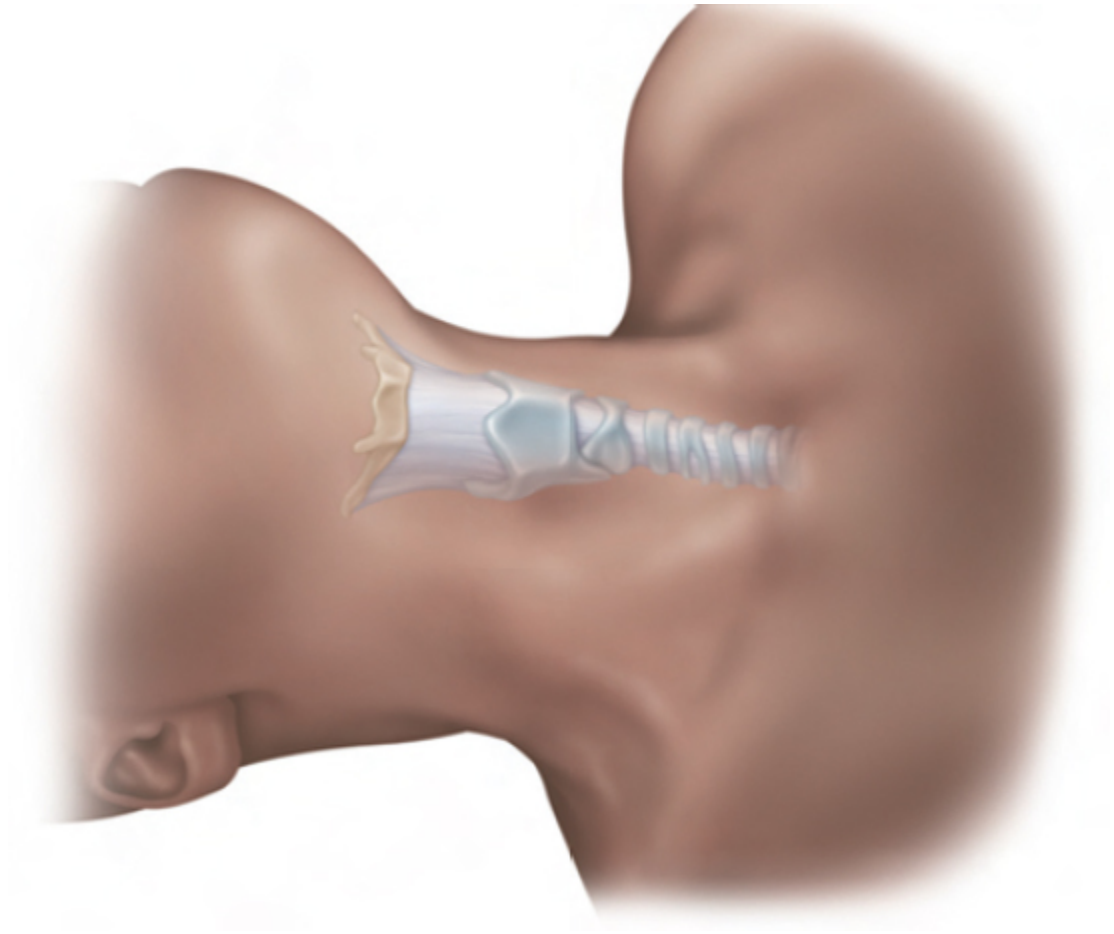

Figure 19.1: Patient in the supine position. (© 2020 Airway Management Education Center.)

2. *Immobilize the larynx.* Throughout the procedure, the larynx must be immobilized (**Fig. 19.2**). This is best done by placing the thumb and long finger of the nondominant hand on opposite sides of the superior laryngeal horns, the posterior superior aspect of the laryngeal cartilage. With the thumb and long finger thus placed, the index finger is ideally positioned anteriorly to relocate and reidentify the CTM at any time during the procedure.

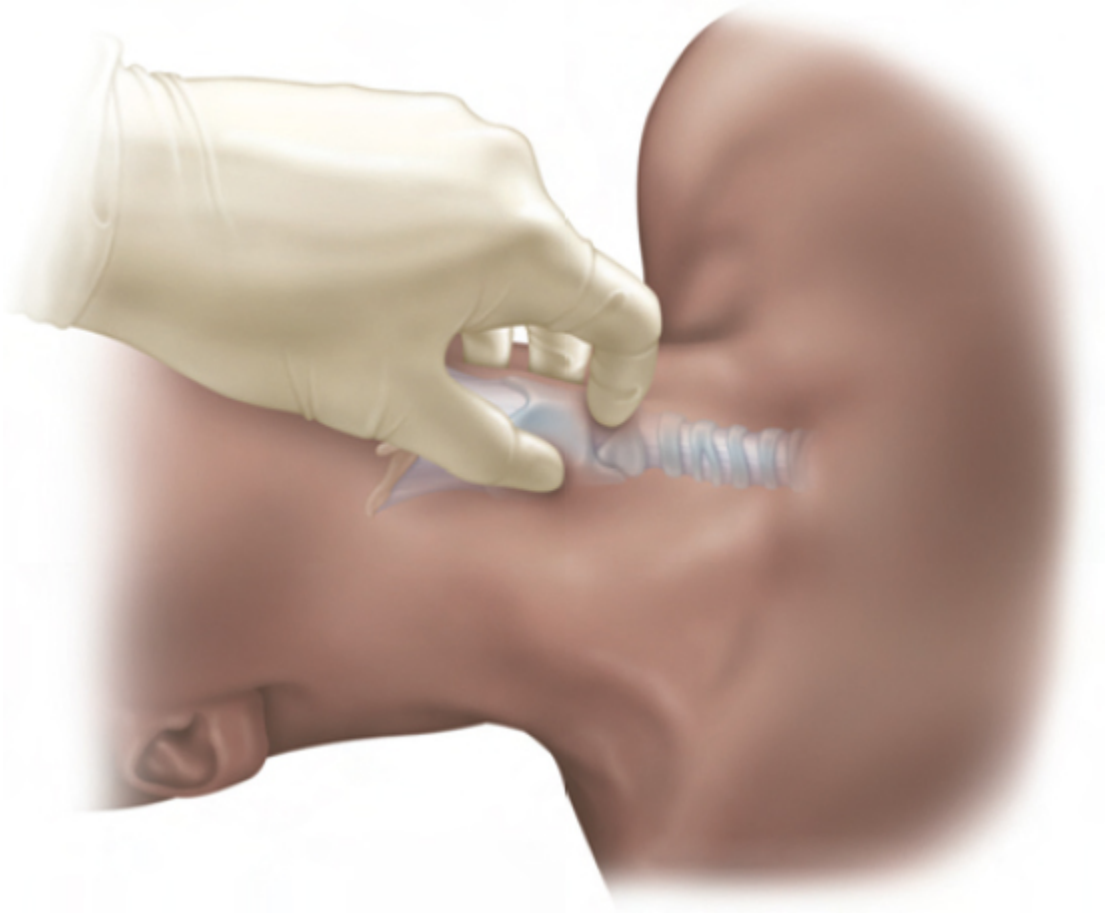

Figure 19.2: Larynx is immobilized with the index finger free to palpate the CTM. (© 2020 Airway Management Education Center.)

3. *Prepare the neck.* If time permits, apply appropriate antiseptic solution. Local anesthesia is desirable if the patient is conscious. Infiltration of the skin and subcutaneous tissue of the anterior neck with 1% lidocaine solution will provide adequate anesthesia. If time permits and the patient is conscious and responsive, anesthetize the airway by injecting lidocaine by trans-cricothyroid membrane puncture. The patient will cough briefly, but the airway will be reasonably anesthetized and further cough reflexes suppressed.
4. *Incise the skin.* Using the dominant hand, a 4- to 8-cm vertical midline skin incision should be made through the skin and soft tissue (**Fig. 19.3**). The incision should begin slightly above the CTM and extend inferior to it. This ensures that the CTM will be exposed within the length of the incision. Expect significant venous bleeding at this point

in the procedure, which will obscure the view of the CTM, but should not delay completion of the procedure.

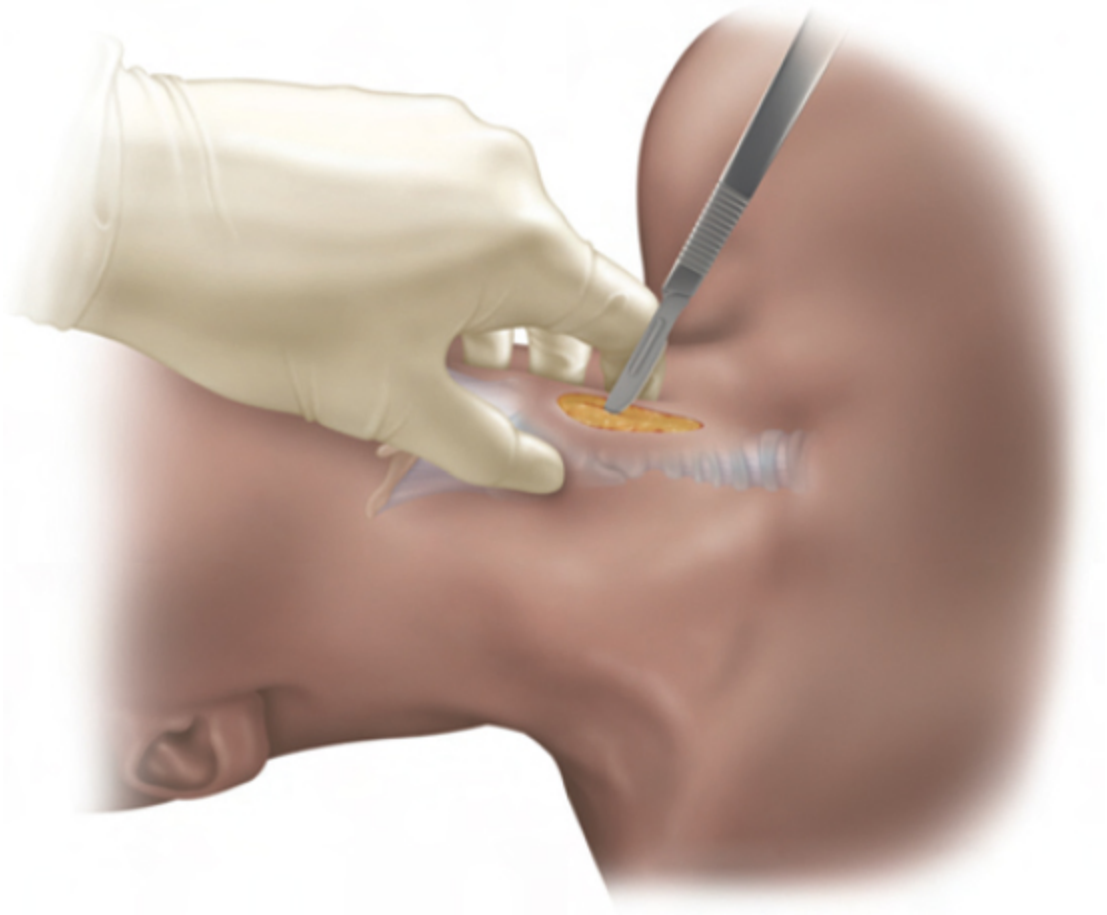

Figure 19.3: Vertical midline skin incision. (© 2020 Airway Management Education Center.)

5. *Reidentify the membrane.* With the thumb and long finger maintaining immobilization of the larynx, the index finger can now palpate the anterior larynx, the CTM, and the cricoid cartilage without any interposed skin or subcutaneous tissue (**Fig. 19.4**). With the landmarks confirmed, the index finger can be left in the incision by placing it on the inferior aspect of the anterior larynx, thus providing a clear indicator of the superior extent of the CTM.

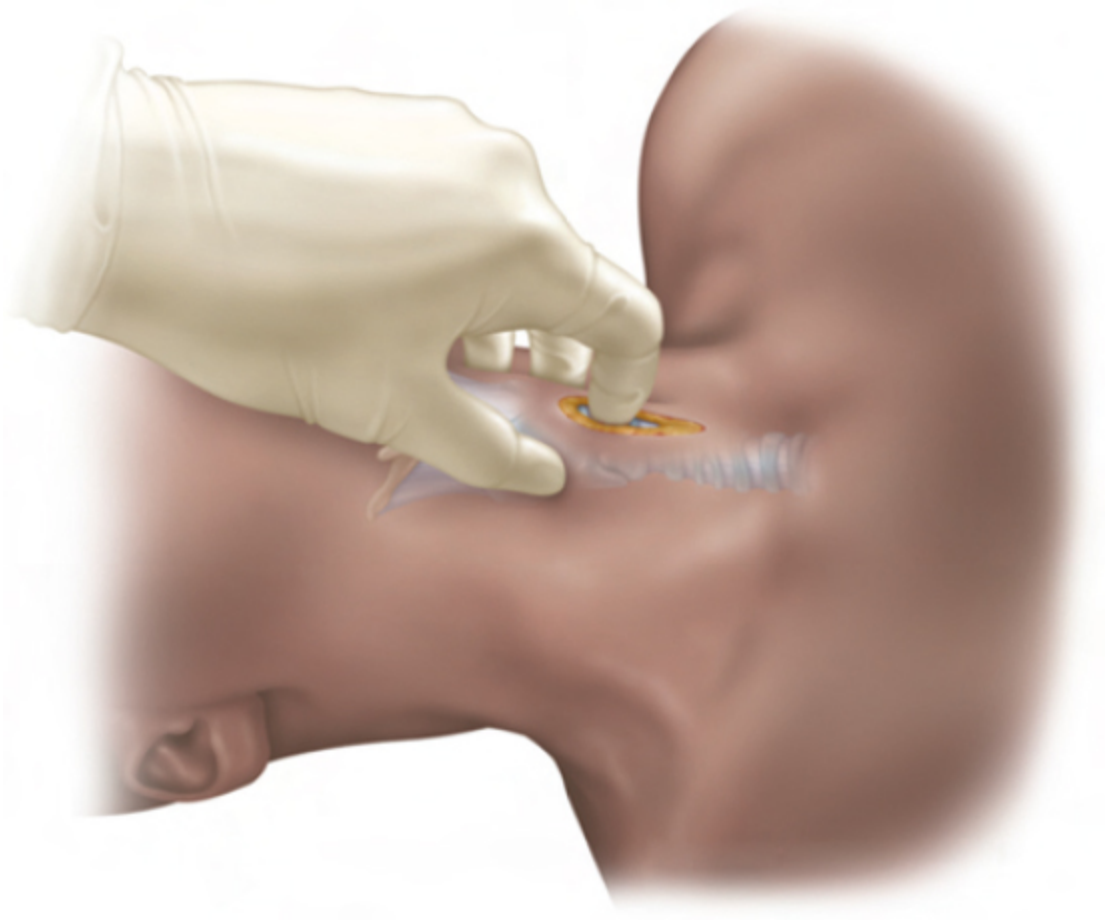

Figure 19.4: Palpation of the anterior larynx, the cricothyroid membrane, and the cricoid cartilage. (© 2020 Airway Management Education Center.)

6. *Stab the membrane.* A stab incision should be made through the cricothyroid membrane and extended horizontally from one edge of the airway to the other (**Fig. 19.5**). Because the scalpel blade will be within airway and contained by the lateral edges of the larynx, there is no significant risk of cutting through important structures when this is done.

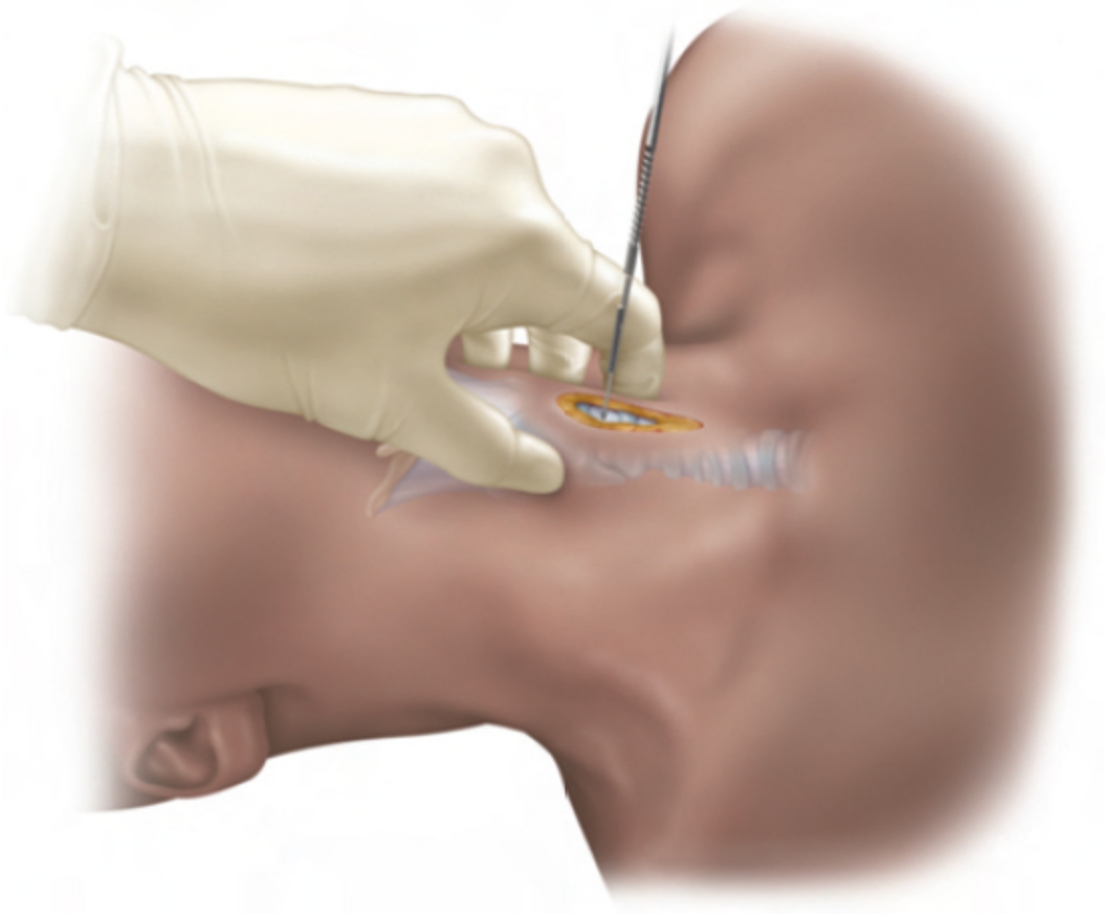

Figure 19.5: Stab incision made through the cricothyroid membrane. (© 2020 Airway Management Education Center.)

7. *Insert the tracheal hook.* With the scalpel blade still inside the CTM incision, the tracheal hook is rotated so that it is oriented in the transverse plane, passed through the incision, and then rotated again so that the hook is oriented in either a cephalad or a caudad direction. The hook is applied to the inferior aspect of the thyroid cartilage or the cricoid cartilage, and gentle upward traction is applied to bring the airway forward, out to the skin incision (**Fig. 19.6**). If an assistant is available, this hook may be passed to the assistant to maintain immobilization of the larynx. At this point in the procedure, the scalpel blade can be removed.

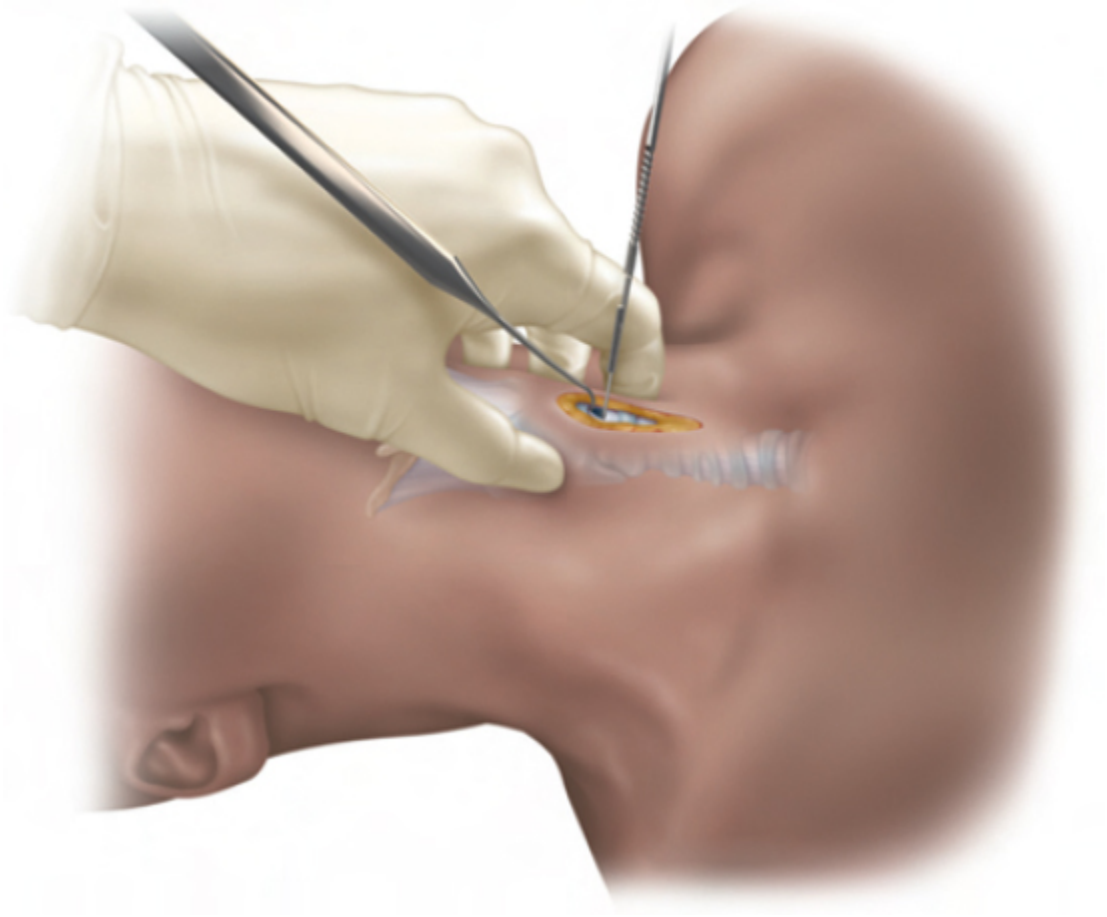

Figure 19.6: Insertion of the tracheal hook. (© 2020 Airway Management Education Center.)

8. *Insert the bougie.* The curved end of a standard (or pediatric) bougie is then advanced through the incision and into the trachea (**Fig. 19.7**). If the tip of the bougie is oriented anteriorly, the familiar feeling of tracheal clicks will be appreciated as it is advanced down the trachea.

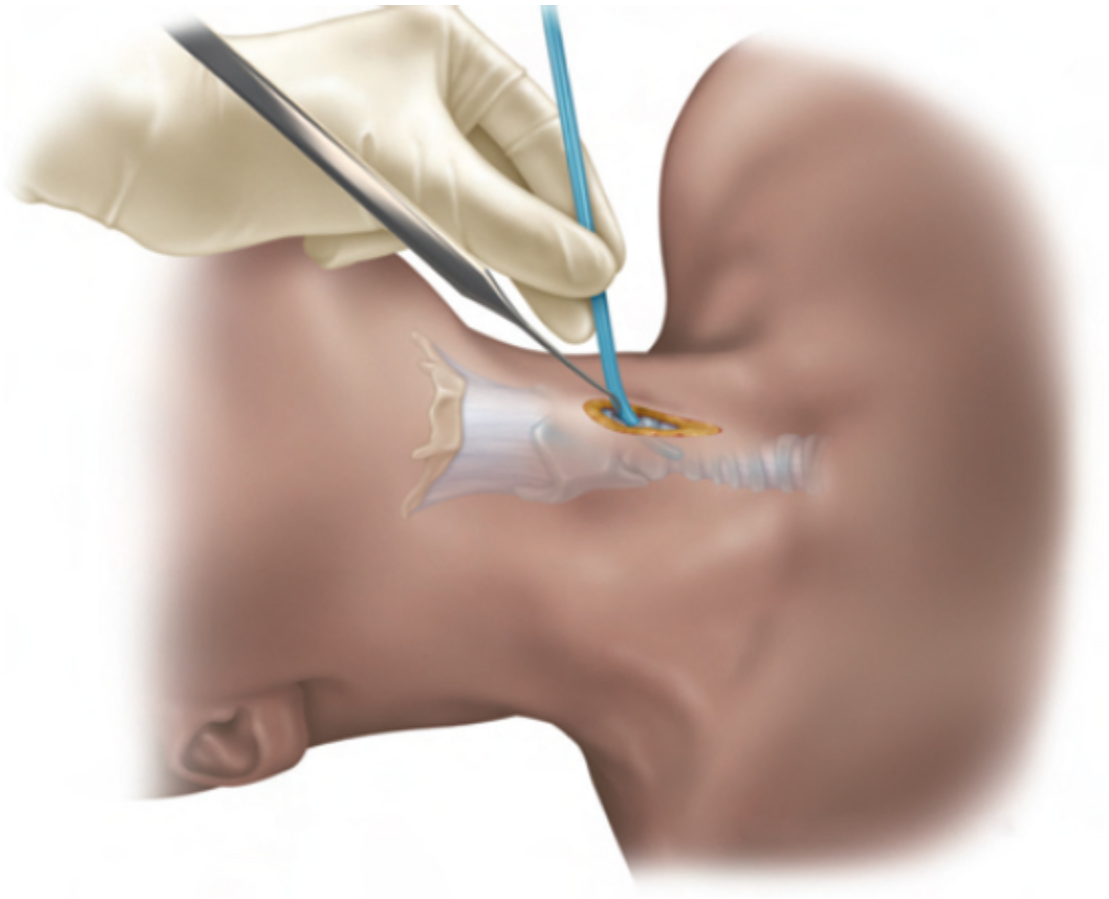

Figure 19.7: Insertion of the bougie. (© 2020 Airway Management Education Center.)

9. *Advance the tube over the bougie.* Advance a standard 6.0 endotracheal tube (ETT) over the bougie (**Fig 19.8**). It is important to note that a slightly smaller caliber ETT may be required in women because their CTMs are often narrower than in men.

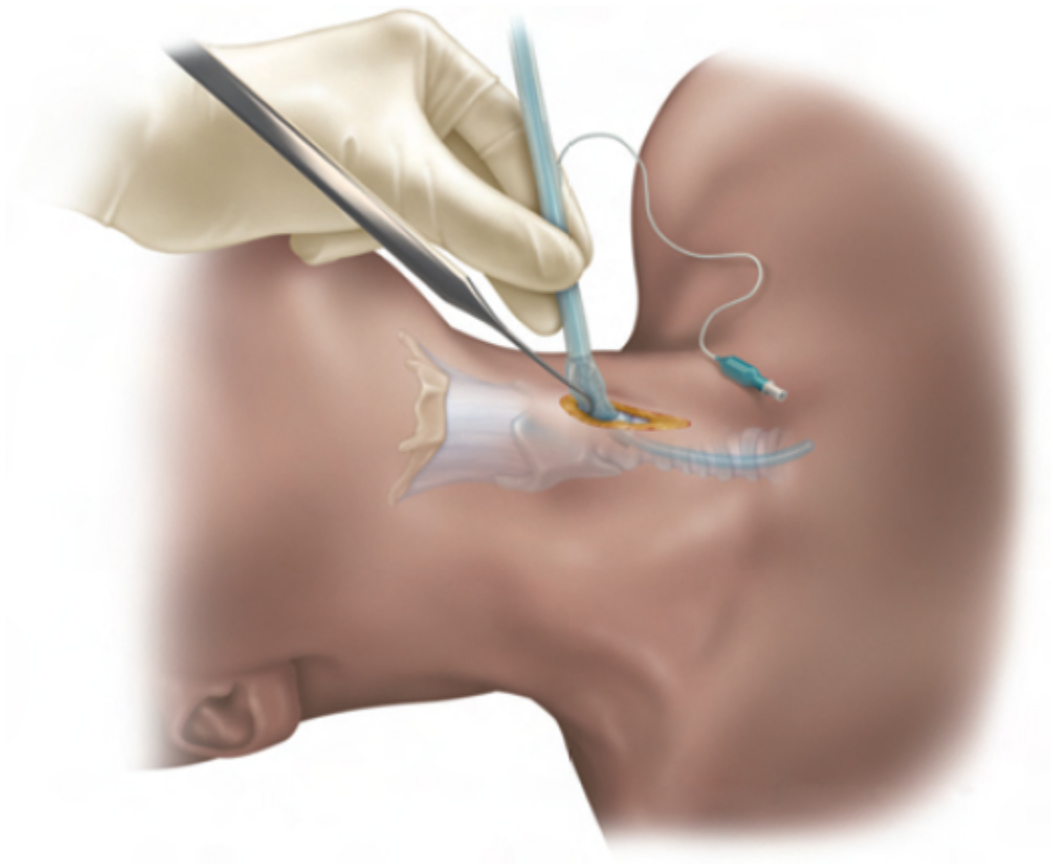

Figure 19.8: Endotracheal tube (ETT) advancement over the bougie. (© 2020 Airway Management Education Center.)

10. *Inflate the cuff and confirm tube position.* With the cuff inflated and while the practitioner holds the tracheal tube in place, proper tracheal tube position can be confirmed by the same methods as for oral ETT position (**Fig. 19.9A-C**). Immediate subcutaneous emphysema with bagging suggests probable extratracheal placement. Understand that esophageal placement of the tracheostomy tube is exceedingly unlikely.

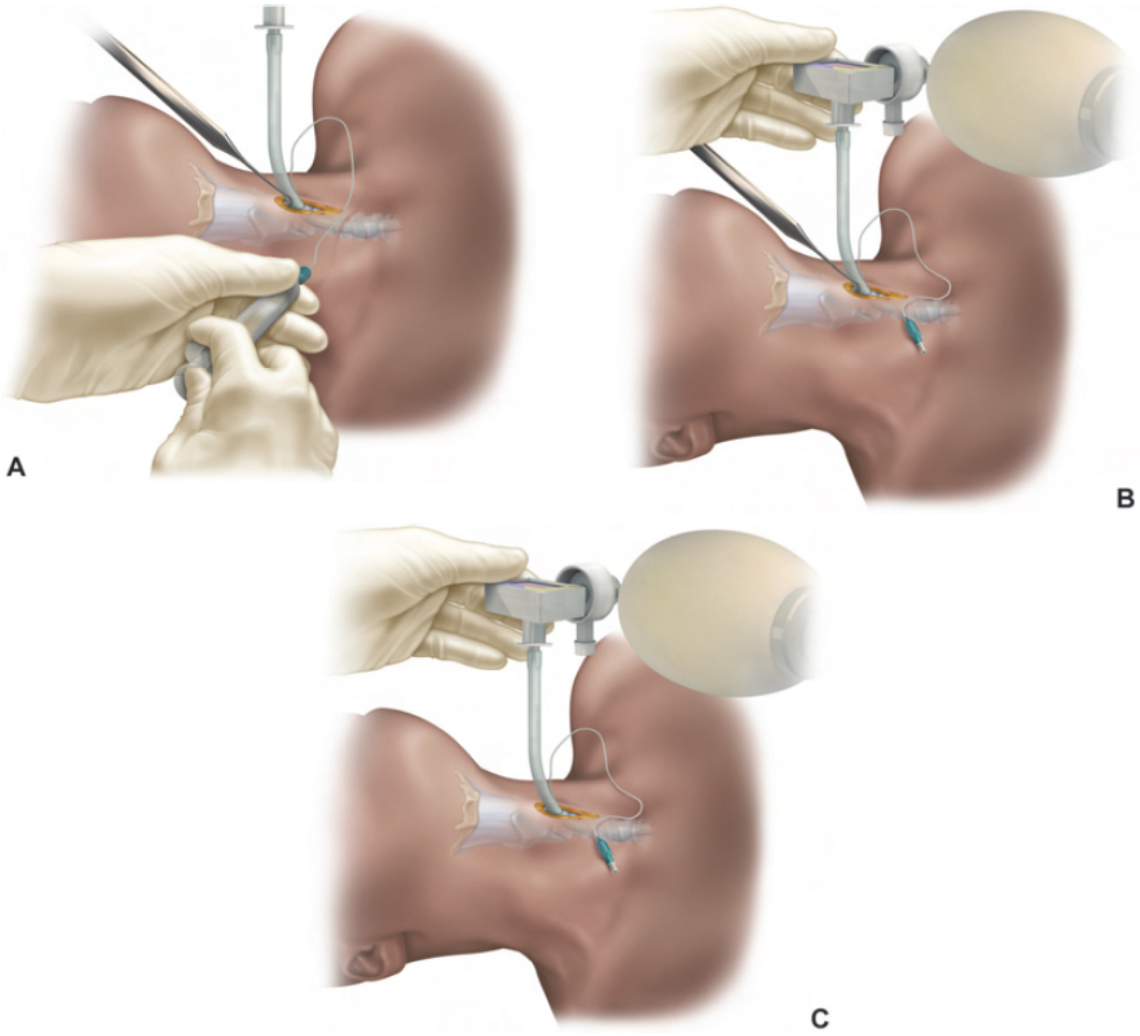

Figure 19.9: Proper tracheal tube position. A. Inflate the tacheal tube balloon after insertion. B. Confirm placement with colorimetric ETCO2. C. Remove tracheal hook. (© 2020 Airway Management Education Center.)

Complications

Because of the high success rate of RSI, cricothyrotomy is infrequently performed in EDs, so reports of complications are difficult to evaluate. In the NEAR III study, only 0.3% of more than 17,500 adult ED intubations required a rescue cricothyrotomy.

The most important complication for the patient in the context of surgical airway management is when delayed decision making and/or persistent ineffective intubation attempts result in hypoxic injury. Emergency surgical airways have a higher complication rate than elective

surgical airways; however, most of these complications are relatively minor, particularly when compared with the consequences of a failed airway.

Box 19.3 lists complications of surgical airway management.

BOX 19.3 Complications of Surgical Airway Management

– Hemorrhage - universal and predominantly venous
– Laceration of the larynx, cricoid ring, or trachea
– Barotrauma and/or pneumomediastinum
– Infection
– Voice change
– Subglottic stenosis

Alternatives to Open Surgical Techniques

Seldinger Technique

The principal method for surgical access is as described previously, but when an alternative to open cricothyrotomy is desired, we recommend using a Seldinger technique. Commercially available kits are available from an array of manufacturers. This method is similar to the one commonly used in the placement of central venous catheters and offers some familiarity to the operator uncomfortable with or inexperienced in the surgical cricothyrotomy techniques described previously. Devices that incorporate an inflatable cuff are recommended.

The individual steps of the procedure are as follows:

Step #1: Identify landmarks
Step #2: Immobilize the larynx
Step #3: Prepare the neck
Step #4: Insert the locator needle
Step #5: Insert the guidewire
Step #6: Incise the skin
Step #7: Insert the tube and dilator
Step #8: Remove the dilator
Step #9: Inflate the cuff and confirm tube placement

1. *Identify landmarks.* As in the open technique (see previous section) (**Figs. 19.10** and **19.11**).

Figure 19.10: Seldinger technique landmark identification. (© 2020 Atrium Health | Michael Gibbs, MD.)

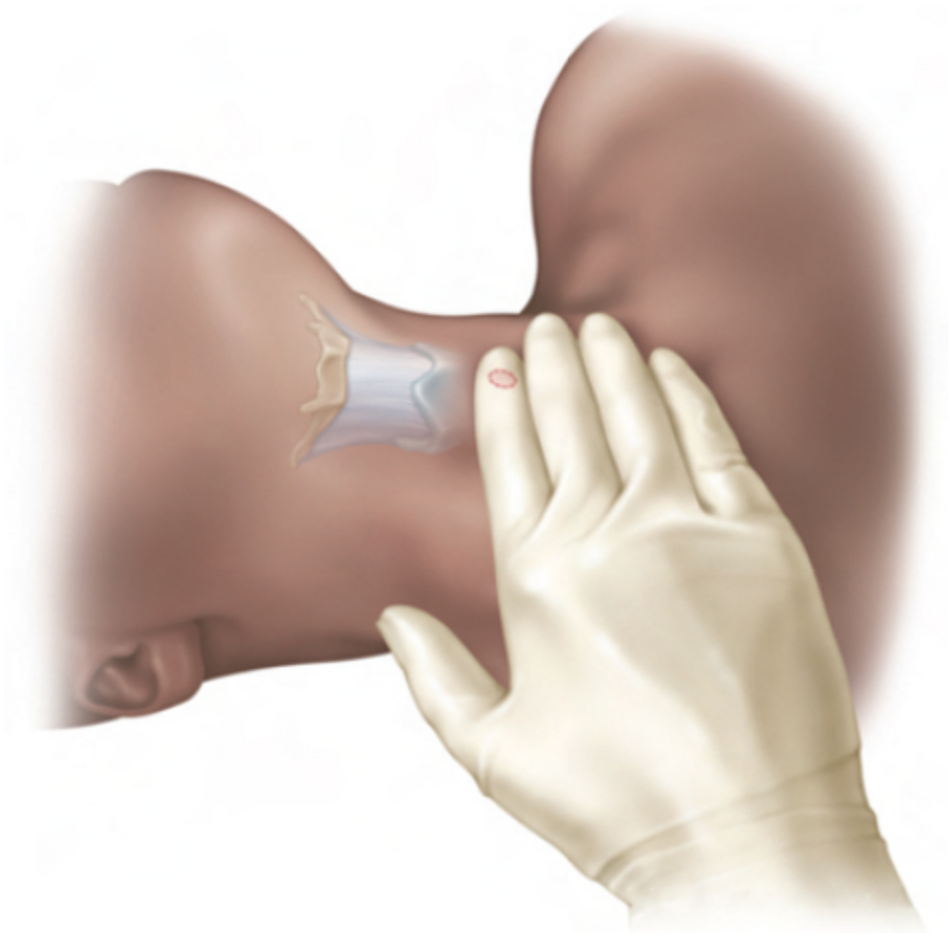

Figure 19.11: Seldinger technique landmark identification. (© 2020 Atrium Health | Michael Gibbs, MD.)

2. *Immobilize the larynx*. As in the open technique (see previous section) (**Fig. 19.12**)

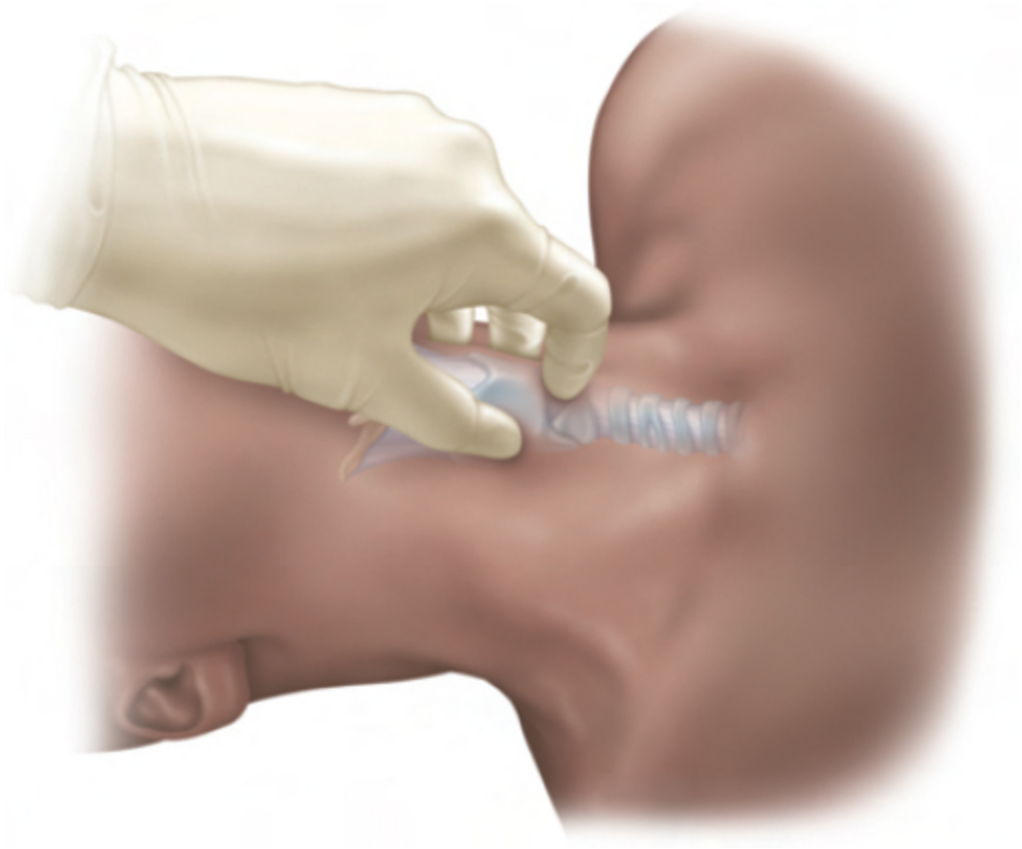

Figure 19.12: Seldinger technique larynx immobilization. (© 2020 Atrium Health | Michael Gibbs, MD.)

3. *Prepare the neck.* As in the open technique (see previous section)
4. *Insert the locator needle.* The introducer needle is then inserted into the CTM in a slightly caudal direction (**Fig. 19.13**). When landmarks are indistinct, an alternative approach involves making a vertical skin incision first followed by needle insertion (**Fig. 19.14A-C**). The needle is attached to a syringe and advanced with the dominant hand while negative pressure is maintained on the syringe (**Fig. 19.15**). The sudden aspiration of air indicates placement of the needle into the tracheal lumen.

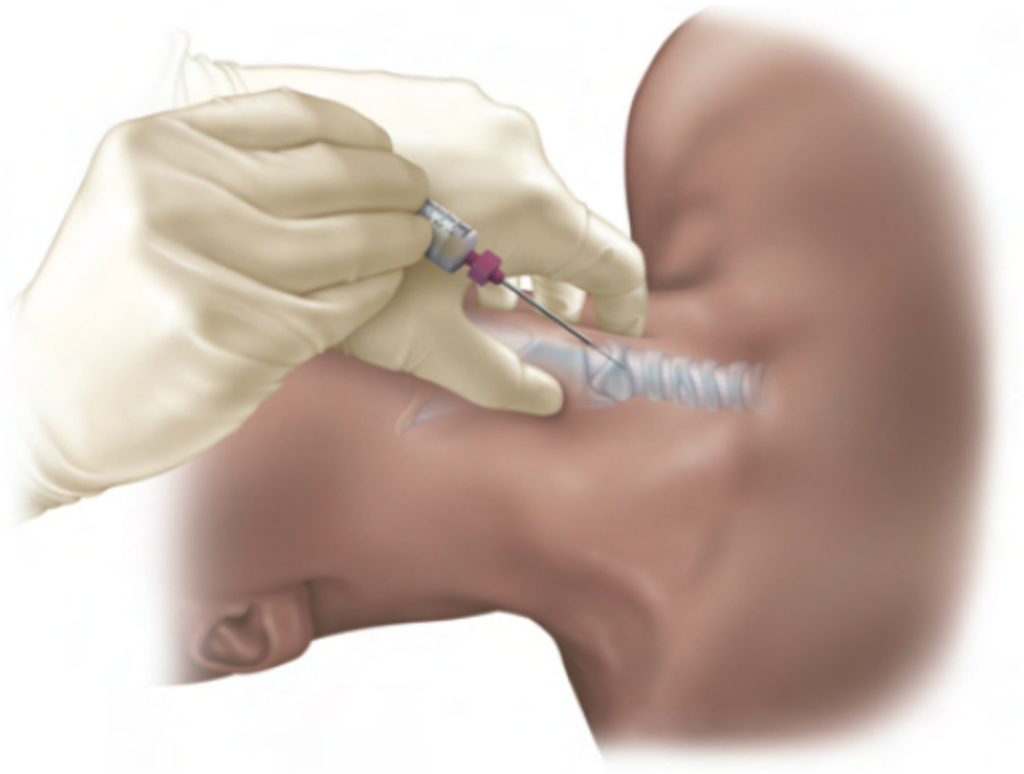

Figure 19.13: Seldinger technique locator needle insertion. (© 2020 Atrium Health | Michael Gibbs, MD.)

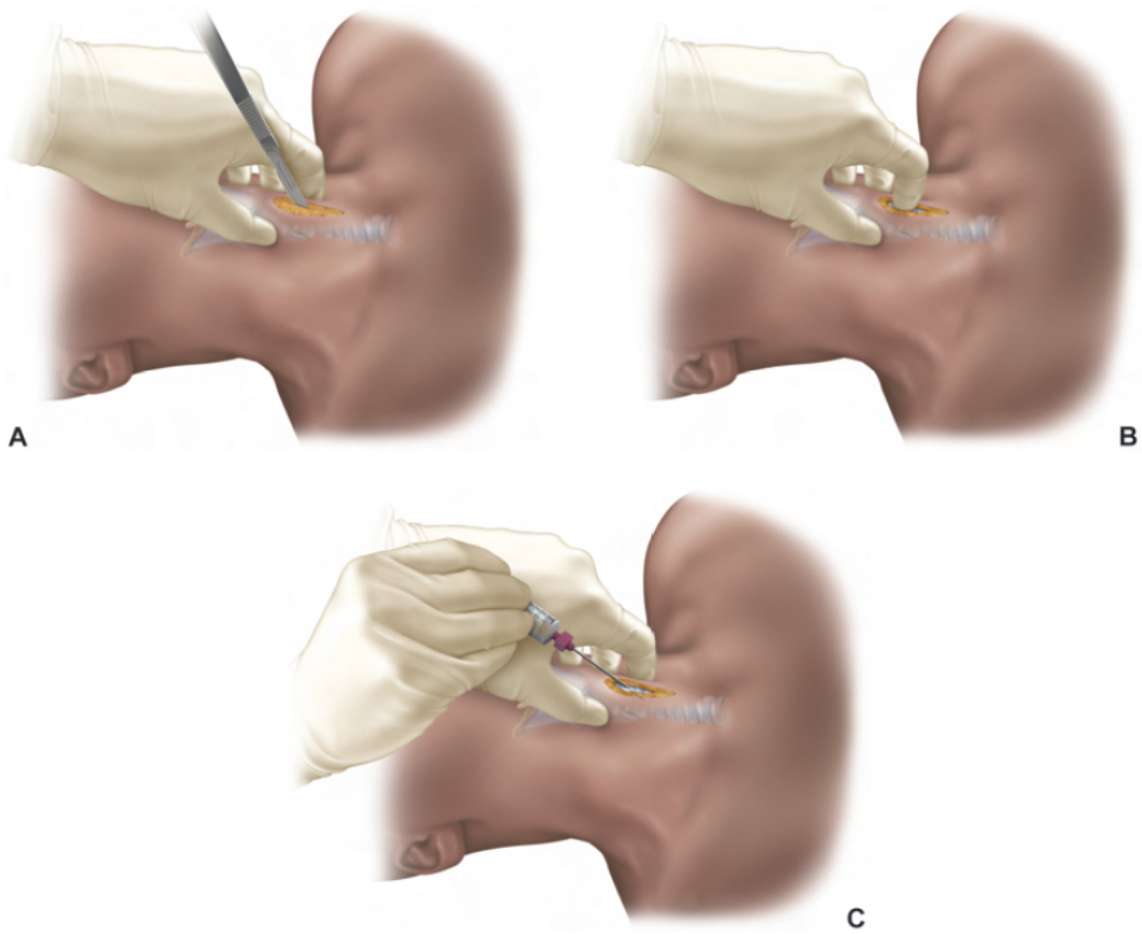

Figure 19.14: Alternative approach to the Seldinger technique locator needle insertion. A. Vertical incision is made with scalpel. B. Landmarks are reconfirmed using index finger. C. Finder needle is placed through the CTM. (© 2020 Atrium Health | Michael Gibbs, MD.)

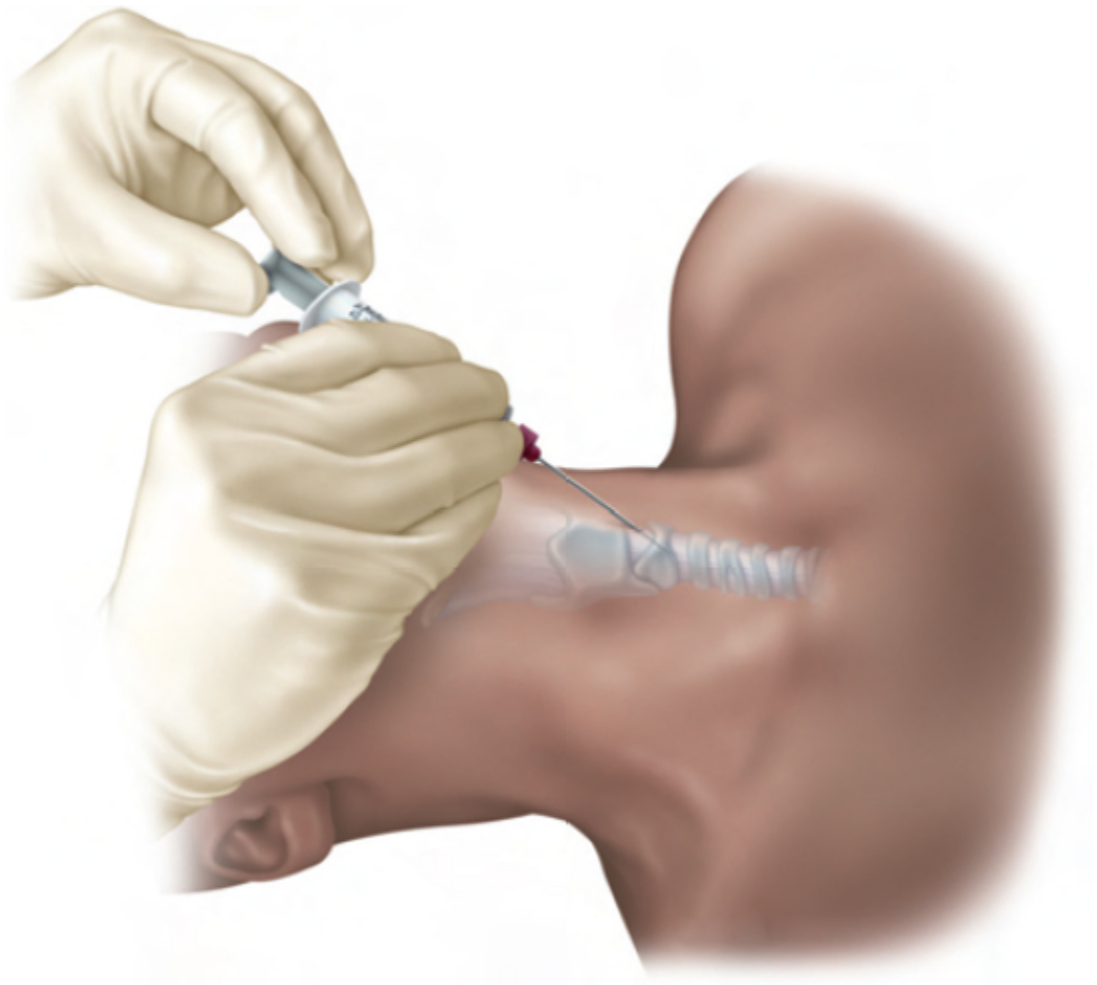

Figure 19.15: Seldinger technique locator needle insertion (© 2020 Atrium Health | Michael Gibbs, MD.)

5. *Insert the guide wire.* The syringe is then removed from the needle. A soft-tipped guide wire is inserted through the needle into the trachea in a caudal direction (**Figs. 19.16** and **19.17**).

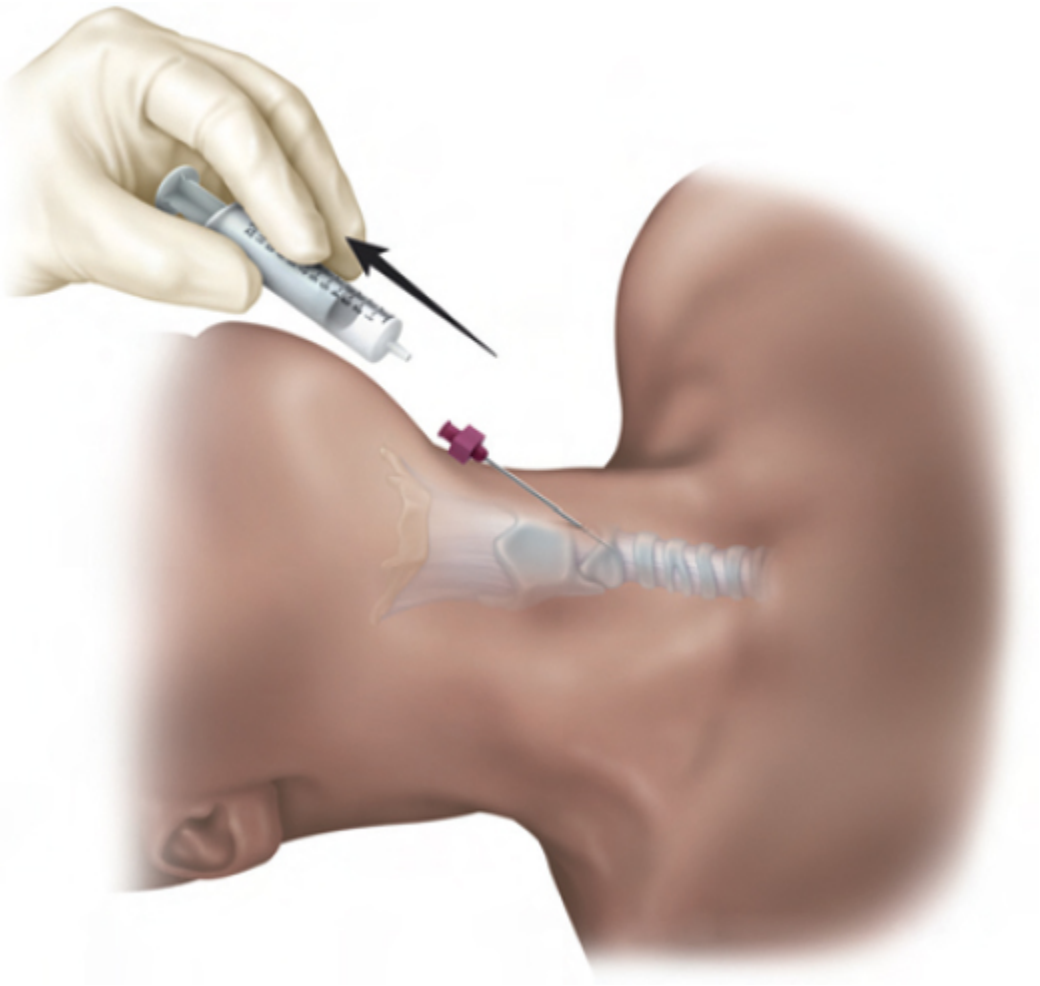

Figure 19.16: Removal of syringe once the finder needle has entered the trachea. (© 2020 Atrium Health | Michael Gibbs, MD.)

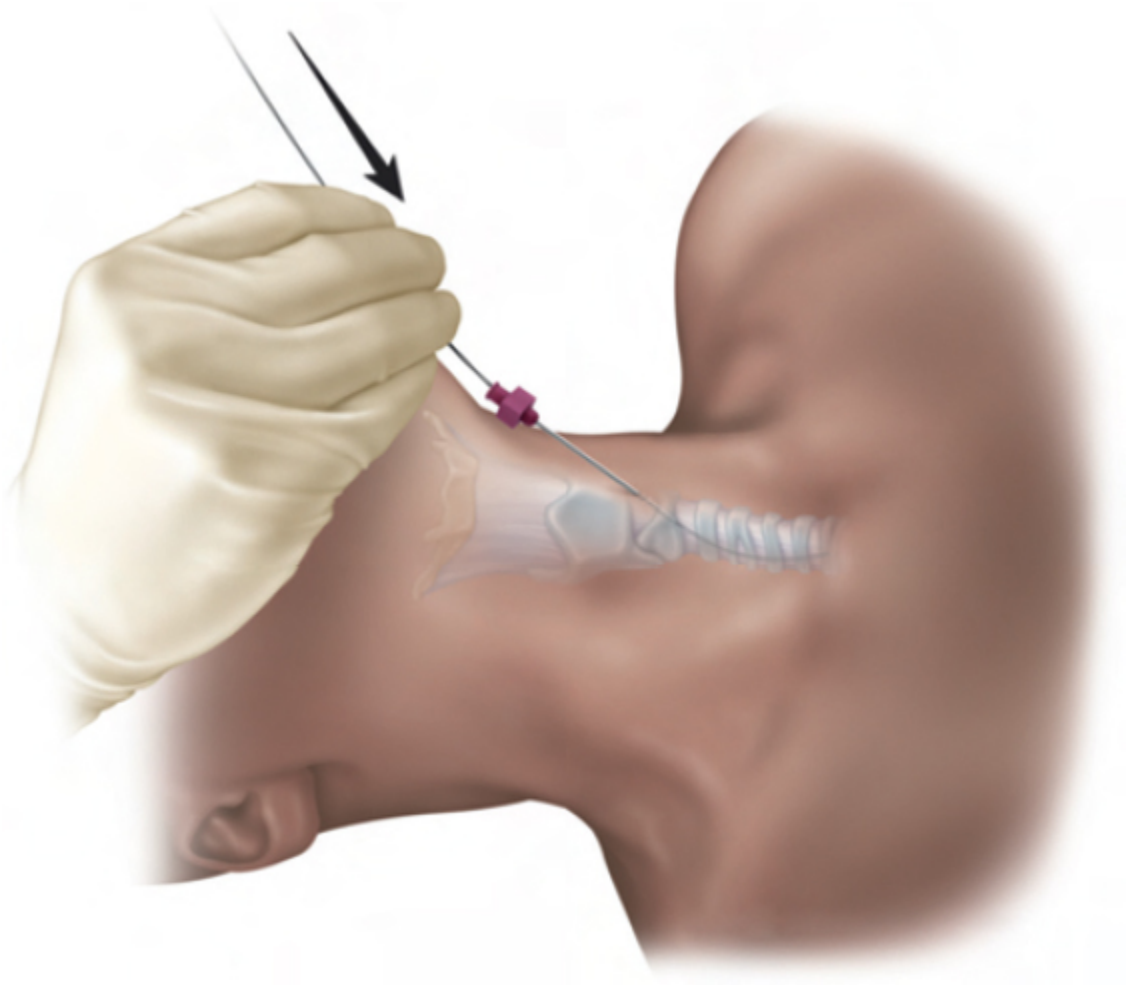

Figure 19.17: Seldinger technique insertion of the guide wire. (© 2020 Atrium Health | Michael Gibbs, MD.)

The needle is then removed, leaving the wire in place. Control of the wire must always be maintained (Fig. 19.17).

6. *Incise the skin and remove the wire.* A small skin incision is then made adjacent to the wire. This facilitates passage of the airway device through the skin (**Figs. 19.18** and **19.19**).

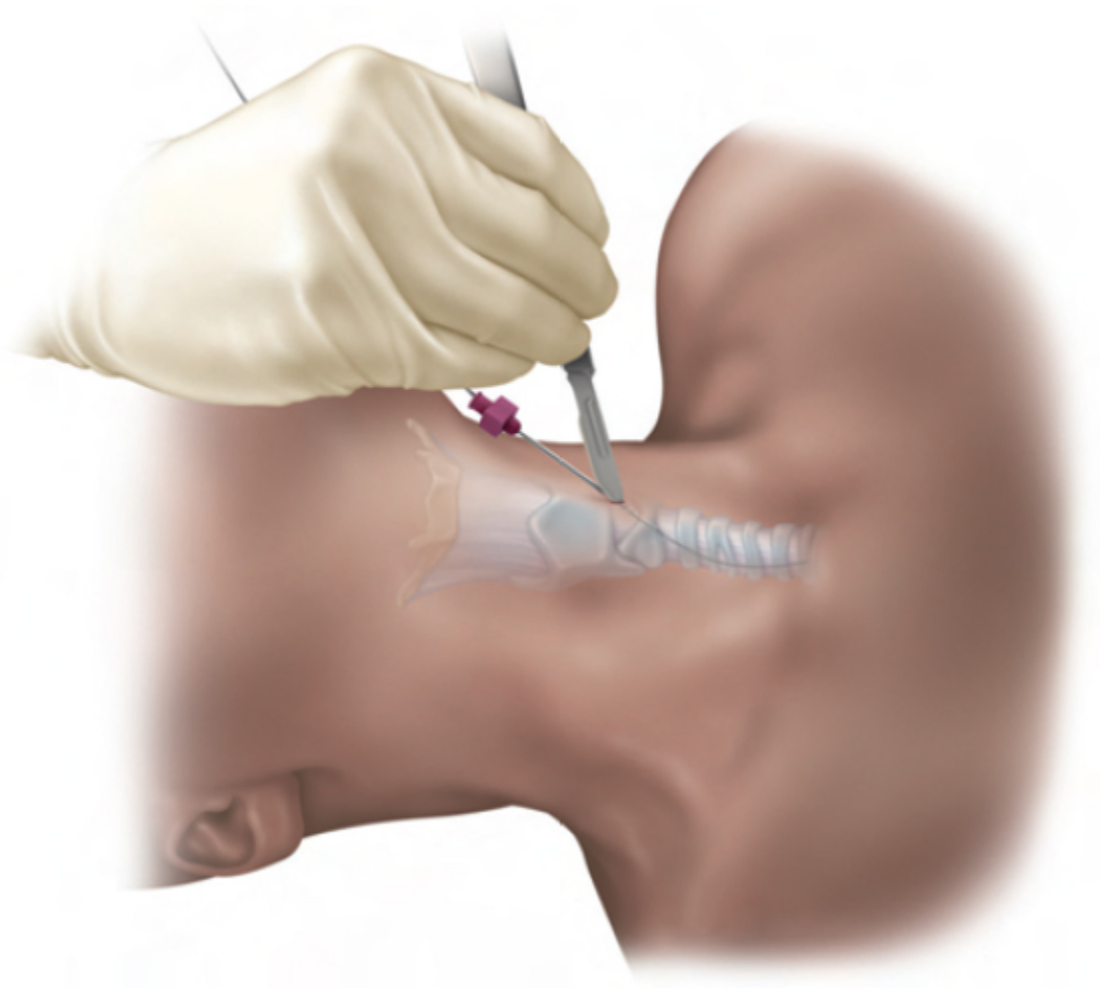

Figure 19.18: Seldinger technique skin incision and wire removal. (© 2020 Atrium Health | Michael Gibbs, MD.)

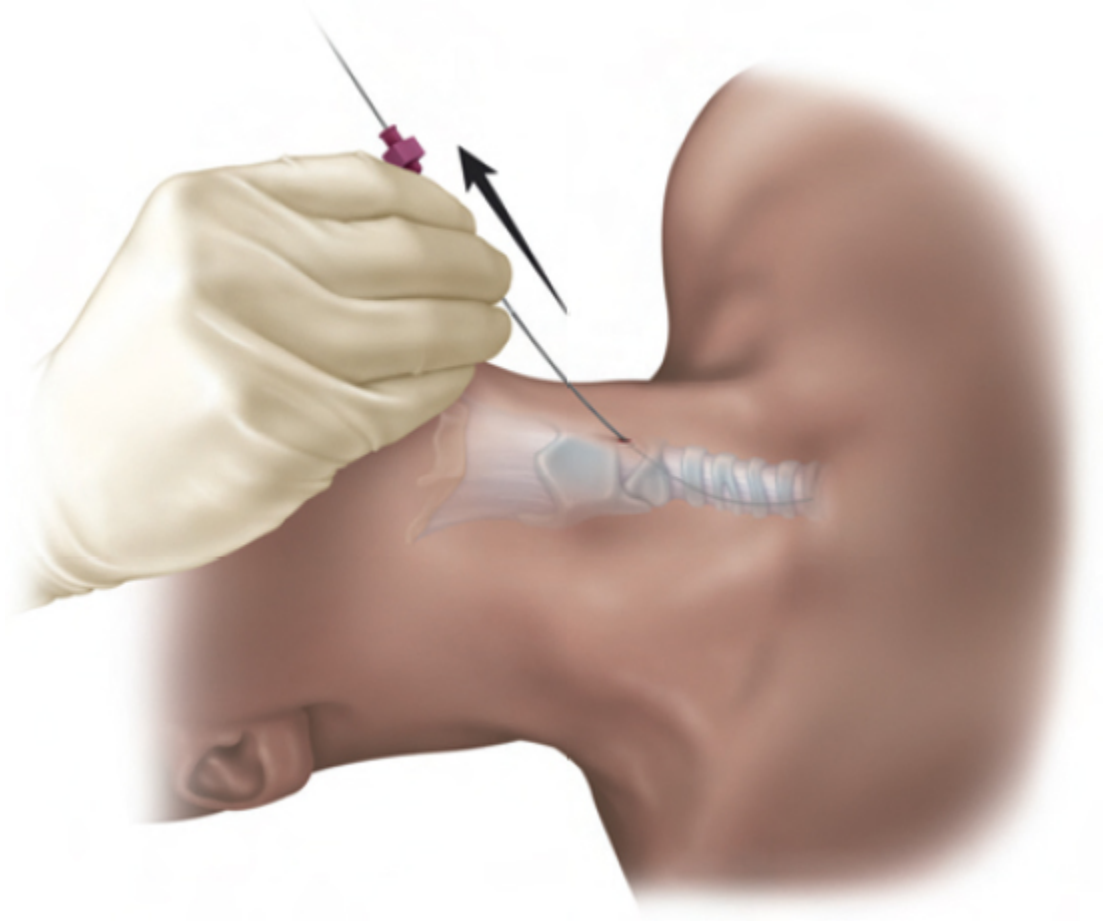

Figure 19.19: Seldinger technique skin incision and wire removal. (© 2020 Atrium Health | Michael Gibbs, MD.)

7. *Insert the airway and dilator.* The airway catheter (3- to 6-mm internal diameter [ID]) with an internal dilator in place is inserted over the wire into the trachea (**Fig. 19.20**). If resistance is met, the skin incision should be deepened and a gentle twisting motion applied to the airway device as it is firmly seated in the trachea. The wire and dilator are then removed together while taking care to hold the tracheal tube in position (**Fig. 19.21**).

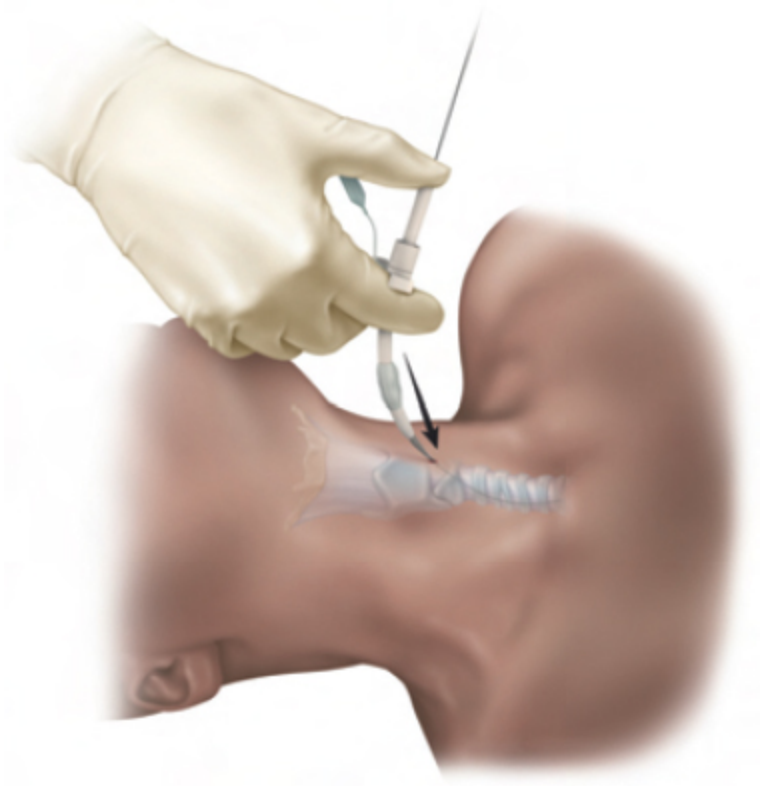

Figure 19.20: Seldinger technique airway and dilator insertion. (© 2020 Atrium Health | Michael Gibbs, MD.)

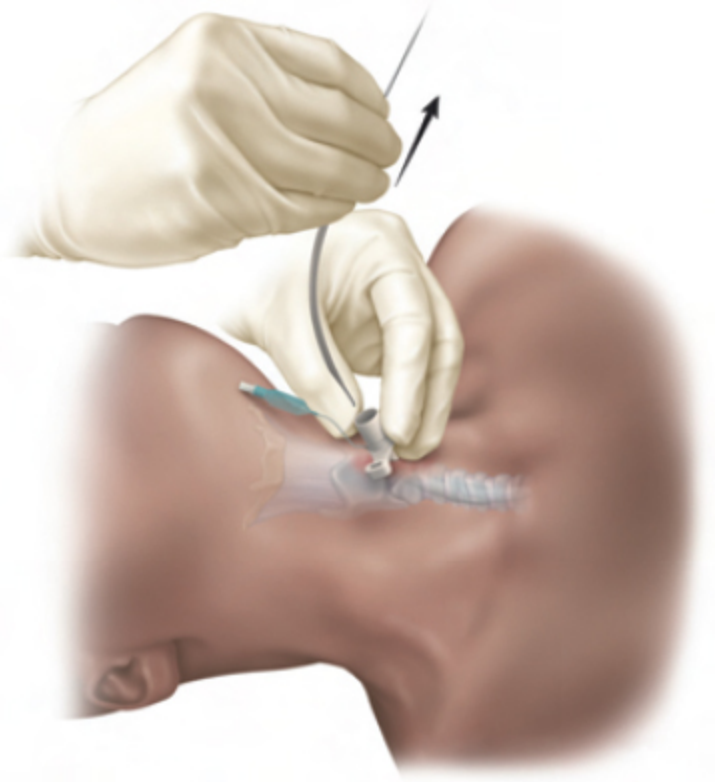

Figure 19.21: Seldinger technique airway and dilator insertion. (© 2020 Atrium Health | Michael Gibbs, MD.)

8. *Confirm tube location.* If the device has a cuff, inflate it at this time. Tube location is confirmed in the usual manner, including mandatory end-tidal CO_2 detection. The airway must then be secured properly (**Fig. 19.22**). The devices are radiopaque on radiographs.

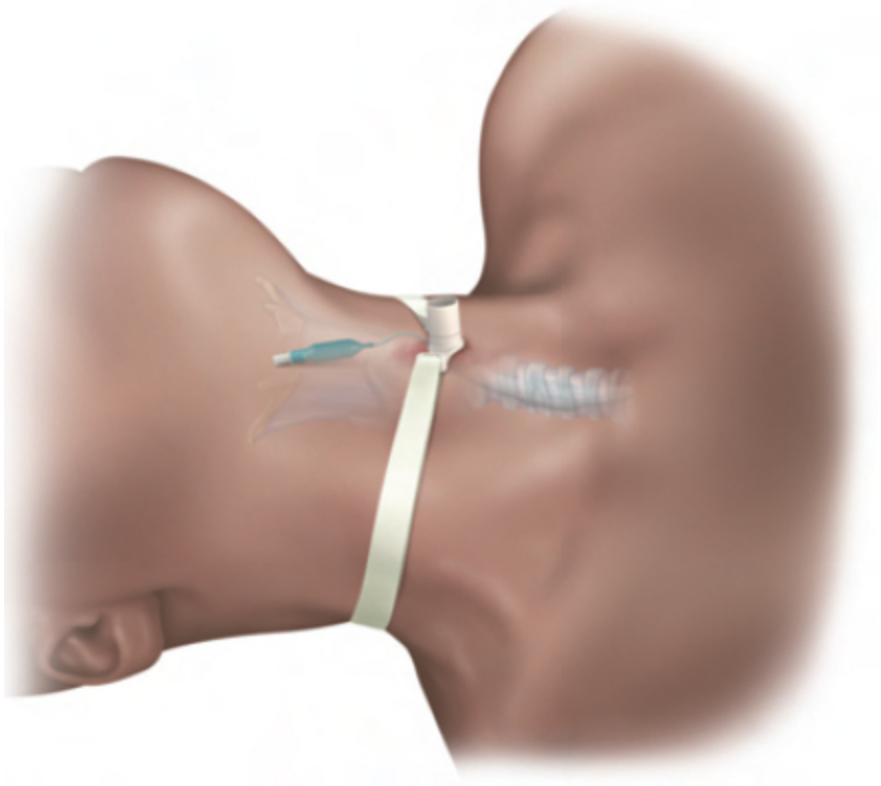

Figure 19.22: Seldinger technique tube location confirmation. (© 2020 Atrium Health | Michael Gibbs, MD.)

Direct Airway Placement Devices

Numerous commercial cricothyrotomy devices are available. These devices, such as Nu-Trake and Pertrach, generally involve the insertion of a large device that functions as both the introducer and the airway. These purport to place an airway simply and rapidly, but none of these has an adequate safety and performance record to warrant a recommendation for emergency use, and the incidence of injury to the airway is higher than in cases where a Seldinger technique is used. These devices offer no clear advantage in technique, are rarely (if ever) as easily placed as is claimed, and are more

likely to cause traumatic complications during their insertion than those that use a Seldinger technique, primarily because of the cutting characteristics of the airway device.

TIPS AND PEARLS

Emergency Surgical Airways

- A simple technique that uses readily available equipment and that has a high success rate for novices is best in the emergency setting, because surgical airways are rare and most providers have limited experience with this procedure.
- An open scalpel bougie-aided technique is recommended. Although appealing on the surface, needle-guided techniques have higher failure and complication rates when used in the emergency setting (see Evidence section).
- Percutaneous palpation of the airway anatomy may be misleading, so an initial midline vertical incision through the skin and soft tissue is recommended. This allows direct palpation of the airway anatomy prior to incising the airway.
- Placing a bougie into the airway incision is technically easier than placing a tube directly and provides some feedback when it is correctly placed inside the trachea. Whenever possible, bougies are placed before the ETT.
- Using a small-diameter hook to stabilize the airway structures prior to placing the bougie is recommended and is especially important in obese patients when the airway anatomy is several centimeters deep to the skin incision.
- Use a standard cuffed ETT. A tracheostomy tube may not be readily available, may be more difficult to place over the bougie, may have multiple unfamiliar pieces (eg, Shiley tracheal tube), and may not be long enough in an obese or swollen neck.
- Mainstem intubation is common when a standard ETT is used, so be aware of this and adjust the depth appropriately.

- In children less than 10 years of age, an open cricothyrotomy is contraindicated because the CTM is smaller and damage to the laryngeal structures is more likely.
- Transtracheal needle jet ventilation has been taught as the primary backup technique in pediatrics for the "cannot intubate and cannot ventilate" scenario for more than 20 years; however, there is no evidence to support this recommendation (see Evidence section).
- The thought of performing an emergency surgical airway on a small child or infant is terrifying to most providers. The best way to avoid this situation is to have modern adjuncts of every size readily available, such as second-generation extraglottic devices that can provide ventilation and oxygenation in nearly all pediatric patients and a conduit for intubation.

EVIDENCE

Should an emergency surgical airway be viewed as a failure?

No. Although employed during can't intubate, can't oxygenate "failed" scenarios, cricothyrotomy should not be viewed as a failure.[1,2] This is a systems problem that needs to be corrected at department, institution, and specialty training levels.[3] Systems need to provide education, equipment, and a solid plan, and providers need to know that a surgical airway should instead be viewed as an essential, life-saving procedure in the right clinical setting. Use of a simple algorithmic approach to emergency airway management (see Chapter 5) helps providers quickly recognize when the procedure is indicated and helps them to view this procedure as just another step in the algorithm rather than a failure.[4-6]

How often are emergency surgical airways performed in the ED setting?

A surgical airway is an infrequent procedure in emergency department populations. In a 2015 report from the NEAR III, a surgical airway was used in 0.5% of 17 583 adult ED intubations.[7] It was used as the initial airway procedure in 0.2% and as a rescue technique after other intubation techniques failed in 0.3%. In a report of pediatric airway management from

the same registry, not a single case of surgical airway management was recorded in more than 1000 pediatric intubations.[8]

Is an open scalpel technique or a needle cannula technique best for emergency surgical airways?

An open scalpel technique is recommended for emergency surgical airways. There has been a debate in the anesthesiology literature about the relative merits of needle cannula (Seldinger, ie, needle-guide wire-cannula) techniques. However, the 4th National Audit Project (NAP4) of major airway complications in the United Kingdom evaluated 79 failed airways in the hospital setting that required a surgical airway and found only a 2% failure rate for open surgical airway techniques compared with a 65% failure rate for a needle cannula techniques.[1] These findings led to the Difficult Airway Society's strong recommendation for the use of scalpel cricothyrotomy techniques.[5] Data from the NEAR in the United States and data from the 4th National Audit Project in the United Kingdom show that in emergency departments open scalpel techniques are used exclusively.[9,10]

Is there evidence that the bougie-guided technique, utilizing a hook and a standard endotracheal tube, is better than the traditional cricothyrotomy technique?

Yes. It is very difficult to study emergency surgical airways because they are so rare. Clinical studies are nearly impossible, so live animal studies might be the next best option. Two randomized studies in a live animal model showed that the bougie-guided technique is better for novices.[11,12] In both studies (one with normal sheep, one with "obese" sheep), novices were randomized to watch a video and then perform the traditional technique (published in the New England Journal of Medicine) or the bougie-guided technique, and in both studies the bougie-guided technique was found to be faster and more successful.[13,14]

What is the best technique for identifying the cricothyroid membrane?

Although this may be impractical in the emergency setting, several meta-analyses show that ultrasound is the best way to identify the CTM, and this is especially important in females and obese patients.[15-17] Landmark and palpation techniques are less reliable for identification of the CTM,

especially in females and obese patients, with success rates ranging from 24% to 72%.[18-20] This is not just a theoretic problem; in the first reported case series of emergency department cricothyrotomies 10% were misplaced *above* the thyroid cartilage.[21] In one randomized trial comparing ultrasound to palpation in patients with poorly defined neck landmarks, the sagittal midline (at the level of the cricoid membrane) was misidentified by 1.5 to 2.3 cm laterally with palpation alone.[22] In addition, a study of 500 patients undergoing CT scans, no patient had a major vessel overlying the CTM, but 9% had a major vessel (most commonly the brachiocephalic artery) in the midline 20 mm above the sternal notch.[23] Ultrasound has been shown to be easy and accurate in locating and identifying the cricothyroid membrane, and many experts believe that it is the standard of care in patients with potentially difficult airways and poor external landmarks.[24,25] The best way to utilize ultrasound is to mark the skin overlying the CTM prior to commencing airway management. If a surgical airway is later needed, the marking remains accurate if the neck is returned to the same position it was in (usually extended) for the ultrasound exam.[24,26,27]

Is there a role for surgical airways in the prehospital setting?

Yes. Although its use is rare, cricothyrotomy has been widely taught and employed in the prehospital environment. A recent position paper from the National Association of EMS Physicians stated that surgical airways are a reasonable option in the prehospital setting.[28] They cautioned that a surgical airway is not a substitute for other airway management tools and techniques and that it should not be the only rescue option available. Also, they recommended an open scalpel technique, based on a meta-analysis that analyzed the results of 512 prehospital surgical airways, and reported success rates of 66% for needle cricothyrotomy techniques and 91% for open scalpel techniques.[29]

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Section V

Pharmacology and Techniques of Airway Management

20 Rapid Sequence Intubation
21 Sedative-Induction Agents
22 Neuromuscular Blocking Agents
23 Optimizing First Attempt Intubation Success
24 Anesthesia and Sedation for Awake Intubation

CHAPTER 20

Rapid Sequence Intubation

Calvin A. Brown III

Ron M. Walls

DEFINITION

Rapid sequence intubation (RSI) is the administration, after preoxygenation and physiologic optimization, of a potent induction agent, followed immediately by a rapidly acting neuromuscular blocking agent (NMBA) to induce unconsciousness and motor paralysis for tracheal intubation. The technique is designed to achieve intubation often without the need for bag-mask ventilation of the unprotected airway in order to minimize the risk of aspiration of gastric contents. Patients requiring emergency intubation have not fasted as they would before a scheduled procedure and, therefore, are at risk for aspiration. The preoxygenation phase, which begins before drug administration, permits a period of apnea to occur safely between the administration of the drugs and intubation of the trachea, typically, without the need for interposed bag-mask ventilation. Likewise, physiologic optimization is a step focused on maximizing patient hemodynamics and overall physiology before RSI drugs are given to minimize the likelihood and severity of circulatory collapse during or immediately after the intubation. In other words, RSI is intended to render the patient unconscious and paralyzed and then to intubate the trachea, with the patient maintaining oxygenation and hemodynamic stability to the greatest extent possible. Effective preoxygenation removes the need, in most cases, to perform bag-mask ventilation while the drugs take effect, even during apnea. Bag-mask ventilation may insufflate the stomach and increase the risk of aspiration. Occasionally, patients at high risk for desaturation but at low risk for aspiration may require gentle and deliberate manual bagging to slow the rate of desaturation while RSI medications take effect and intubating

conditions are achieved. The Sellick maneuver (posterior pressure on the cricoid cartilage to occlude the esophagus and prevent passive regurgitation), although once widely recommended, has no proven benefit and may worsen intubating conditions and so is no longer used.

Indications and Contraindications

RSI is the cornerstone of emergency airway management and the technique of choice when emergency intubation is indicated, and the patient does not have difficult airway features felt to contraindicate the use of an NMBA (see Chapters 2 and 3). Either succinylcholine or rocuronium is an appropriate choice of NMBA for most patients. There are specific contraindications to succinylcholine in a few patients. For these patients, rocuronium is the NMBA of choice (see Chapter 22). In patients without a contraindication to succinylcholine, there is no clear evidence to establish either drug as superior to the other, so operator preference is the guiding principle.

TECHNIQUE

RSI can be thought of as a series of discrete steps, referred to as the seven Ps. Although conceptualizing RSI as a series of individual actions is helpful when teaching or planning the technique, most emergency intubations require that several steps, especially leading up to tube placement, occur simultaneously. The seven Ps of RSI are shown in **Box 20.1**.

BOX 20.1 The Seven Ps of RSI

1. Preparation
2. Preoxygenation
3. Physiologic Optimization
4. Paralysis with induction
5. Positioning
6. Placement with proof
7. Postintubation management

Preparation

Before initiating the sequence, the patient is thoroughly assessed for anatomic or physiologic features that warn of intubation difficulty (see Chapters 2 and 3). Fallback plans in the event of failed intubation are established, and the necessary equipment is located. The patient is in an area of the emergency department that is organized and equipped for resuscitation. Cardiac rhythm, BP, and oxygenation monitoring should be used in all cases. Continuous waveform capnography provides additional valuable monitoring information, particularly after intubation, and should be used whenever possible. The patient should have at least one, and preferably two, secure, well-functioning intravenous (IV) lines. Pharmacologic agents are drawn up in properly identified syringes. Vital equipment is tested. A video laryngoscope (VL) should be brought to the bedside and tested for image clarity because this is most often the device used on first attempt. An endotracheal tube (ETT) of the desired size is prepared, and the cuff is tested for leaks. Prepare a tube 0.5 to 1.0 mm less in internal diameter (ID) if intubation difficulty is anticipated. Selection and preparation of the tube, as well as the use of the intubating stylet and bougie, are discussed in Chapter 15. Throughout this preparatory phase, the patient is receiving preoxygenation and optimization measures, if appropriate, as described in the next two sections.

Preoxygenation

Preoxygenation is the establishment of an oxygen reservoir within the lungs, blood, and body tissue to permit potentially several minutes of apnea to occur without clinically significant arterial oxygen desaturation. The principal reservoir is the functional residual capacity (FRC) in the lungs, which is approximately 30 mL/kg. Administration of high-flow 100% oxygen for 3 minutes replaces this predominantly nitrogenous mixture of room air with oxygen, allowing several minutes of apnea time before hemoglobin saturation decreases to <90% (**Fig. 20.1**). Similar preoxygenation can be achieved much more rapidly by having a cooperative patient take eight vital capacity breaths (the greatest volume of breaths the patient can take) while receiving 100% oxygen. Obese patients are best preoxygenated in the upright position.

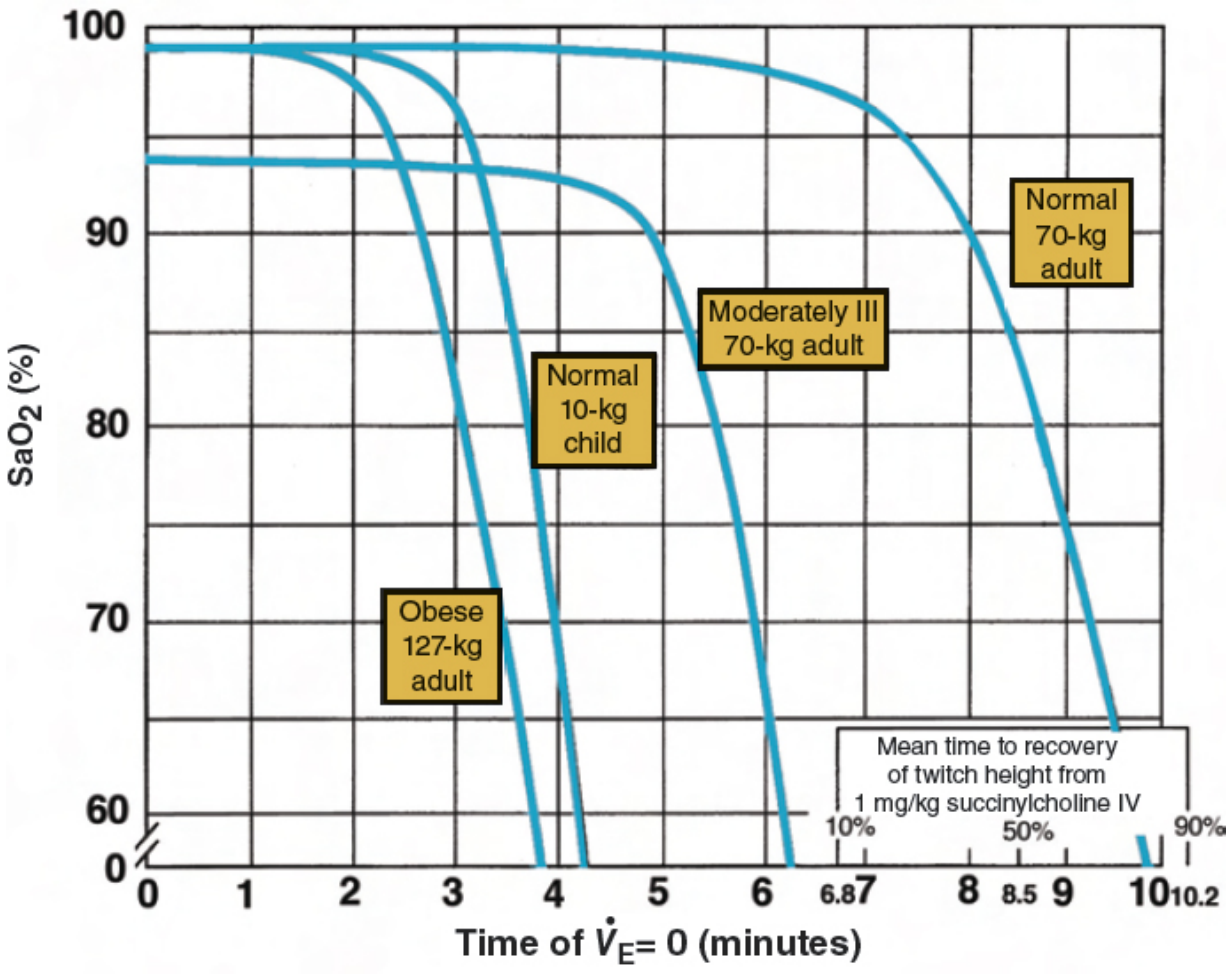

Figure 20.1: Time to desaturation for various patient circumstances. (From Benumof J, Dagg R, Benumof R. Critical hemoglobin desaturation will occur before return to an unparalyzed state following 1 mg/kg intravenous succinylcholine. *Anesthesiology*. 1997;87:979-982.)

Oxyhemoglobin desaturation is significantly delayed if oxygen is continuously administered at 5 to 15 L/min by nasal cannula throughout the intubation sequence. The highest flow rate the patient will tolerate, with a goal of 15 L/min, should be used. The evidence for this technique, called “apneic oxygenation,” is presented at the end of this chapter. This is particularly important for obese patients to mitigate their tendency toward rapid desaturation. We recommend nasal cannula oxygen during the apneic phase of intubation for all emergency department intubations; however, we consider it essential for patients at high risk for rapid desaturation.

The time to desaturation for an individual patient varies. Children, patients with morbid obesity, chronic pulmonary disease, critical illness

(caused by high tissue oxygen extraction), and late-term pregnant women desaturate significantly more rapidly than an average healthy adult.

Note the bars indicating recovery from succinylcholine paralysis on the bottom right of Figure 20.1. This exposes the fallacy that a patient will recover sufficiently from succinylcholine-induced paralysis to breathe on his or her own before sustaining injury from hypoxemia, even if intubation and mechanical ventilation are both impossible. Although some healthy patients with normal body habitus may recover adequate neuromuscular function to breathe on their own before catastrophic desaturation, many others, including almost all children and most patients intubated for emergency conditions, will not, and even those who do are dependent on optimal preoxygenation before paralysis.

A healthy, fully preoxygenated 70-kg adult will maintain oxygen saturation (SaO_2) at >90% for 6 to 8 minutes, whereas an obese adult will desaturate to 90% in <3 minutes. A 10-kg child will desaturate to 90% in <4 minutes. The time for desaturation from 90% to 0% is even more important and much shorter. This is caused by a conformational change that hemoglobin undergoes once it is approximately 7% to 10% desaturated, which allows it to release its remaining oxygen stores much more readily. This is also the basis for our recommendation that an intubation attempt be aborted, and reoxygenation efforts begin, when a declining SpO_2 reaches 93% unless intubation is on the cusp of completion. The healthy 70-kg adult desaturates from 90% to 0% in <120 seconds, and the small child does so in 45 seconds. A late-term pregnant woman is a high oxygen user and has a reduced FRC and an increased body mass, so she desaturates quickly similarly to the obese patient. Caution is required in this circumstance because both the obese patient and the pregnant woman may also be difficult to intubate and to bag-mask ventilate.

Most emergency departments do not use systems that can deliver 100% oxygen. Historically, emergency department patients were preoxygenated using the “100% non-rebreather mask” at 15 L/min flow, the top flow rate indicated by the flow meter on a standard wall-mounted oxygen spigot. At this flow rate, the fraction of inspired oxygen (FIO_2) is roughly 65% to 70%, depending on fit and the patient’s respiratory rate (see Chapter 8). An FIO_2 of 100% is not possible in most cases because the patient’s inspiratory

demand outstrips the inflow rate of 100% oxygen. This is particularly true in patients with respiratory distress, tachypnea, or a minute ventilation >15 L/min. Room air entrainment around the margin of the mask provides the additional required volume drawn by the patient with each breath. Room air, at 1 atmosphere (atm), is 21% oxygen. Therefore, the combination of 100% oxygen at 15 L/min from the reservoir on the NRB mask along with varying volumes of 21% oxygen from room air results in an average F_{IO_2} of 65% to 70%, in most cases. This limitation can be overcome by increasing the inflow rate of 100% oxygen to the "flush-flow rate" (approximately 50 L/min). Despite the indicated maximum flow rate of 15 L/min on the mounted flow meter, this is not the highest flow rate available from a wall-mounted oxygen source. The flush-flow rate is typically indicated by a label affixed to the base of the spigot (**Fig. 20.2**) and can be activated by turning the green flow-control knob to the fully open position. An NRB mask using flush-flow rate 100% oxygen can increase the F_{IO_2} to >90% and is more effective at denitrogenation. We recommend flush-flow rate ambient pressure preoxygenation as the default technique during RSI (see Evidence section later).

Figure 20.2: Wall oxygen flow meter showing maximum available flow rate.

If the oxygen saturation is 93% or less, despite flush-flow rate supplemental oxygen, this indicates the presence of significant intrapulmonary shunting and the need for alveolar recruitment for optimal preoxygenation. In these circumstances, transition the patient from an NRB mask to either bilevel positive airway pressure (Bi-PAP) or high-flow nasal oxygen (HFNO). Both are capable of high flow rates and positive end-expiratory pressure (PEEP), the latter is required to stent open alveoli and reduce ventilation-perfusion (V/Q) mismatch. HFNO can deliver up to 70 L/min of oxygen flow and 5 cm H_2O of PEEP and can be used both for preparatory and apneic oxygenation. Further discussion about oxygen delivery can be found in Chapter 8. The use of pulse oximetry throughout intubation enables the physician to monitor the level of oxygen saturation, eliminating guesswork.

Physiologic Optimization

Patients may be challenging to intubate for anatomic reasons such as airway obstruction or reduced neck mobility. Additionally, overall airway management can be made more complex by compromised physiology reflected by deranged vital signs. Although septic shock, severe myocardial depression, or an inability to preoxygenate in and of themselves do not make the act of laryngoscopy and tracheal tube placement more difficult, they can contribute to operator stress and potential patient morbidity by drastically compressing the time available to safely intubate or by placing the patient at risk for hypoxic injury or peri-intubation circulatory collapse (see Chapter 3). Physiologic optimization involves identifying and mitigating areas of cardiopulmonary vulnerability that may complicate resuscitative efforts, even if tracheal intubation goes quickly and smoothly. Positive-pressure ventilation initiated after successful intubation reduces venous return by increasing intrathoracic pressure and can cause or contribute to severe circulatory compromise in vulnerable patients. If the need for intubation is not immediate, abnormal hemodynamic parameters should be normalized as much as possible prior to intubation. A simple example of this would be the administration of a liter of isotonic fluid and titration of norepinephrine to improve blood pressure in a patient with

hypotension, such as that caused by septic shock, before initiating intubation. Common aspects of abnormal patient physiology that should be identified and addressed during this step are shown in **Box 20.2**. The most encountered physiologic problem is hypotension. Bleeding, dehydration, sepsis, and primary cardiac pathology are common emergency conditions that can complicate patient management, despite successful placement of the ETT. All induction agents can potentiate peripheral vascular dilation and myocardial depression, and patients who present with depressed cardiac function, low intravascular volume, or poor vascular tone can suffer profound refractory shock or circulatory collapse after RSI drugs are administered, particularly when positive-pressure ventilation further compromises venous return. Isotonic fluids, blood products, and pressor agents may be used, time permitting, to support blood pressure and increase pharmacologic options for RSI. Oxygenation efforts are reassessed during this step and escalated if necessary. Patients with hypertensive crises, generally do not require additional treatment if RSI with full induction is planned. Although sympatholytic agents, such as fentanyl, can mitigate the reflex sympathetic response to laryngoscopy, its benefit during emergency RSI is not proven and would not significantly add to sympathetic blockade in patients who have received, essentially, general anesthetic doses of an induction agent. Additionally, no evidence-based dosing guidelines exist for fentanyl during RSI, and the addition of a third agent introduces more risk of a drug administration error and prolongs the intubation sequence. Although not contraindicated during RSI, for this 6th edition, we do not recommend routine fentanyl administration for hypertensive emergencies.

BOX 20.2 Physiologic Optimization During RSI

Fluids or Blood	Hypotension from bleeding, dehydration, sepsis, etc.
Pressors (Norepinephrine or Neo-Synephrine)	Hypotension refractory to fluid challenge
Bi-PAP/CPAP	Hypoxia refractory to face mask oxygen
Tube Thoracostomy	Identified or suspected tension pneumothorax

Paralysis With Induction

In this step, a rapidly acting induction agent is given in a dose adequate to produce prompt loss of consciousness (see Chapter 21). Administration of the induction agent is immediately followed by the NMBA (see Chapter 22). Succinylcholine and rocuronium are the only two NMBAs appropriate for use during RSI. Either agent produces satisfactory intubating conditions within one minute of administration, and the rare but consequential adverse effects of succinylcholine in certain patient groups has led some providers to choose rocuronium as their routine NMBA for RSI. Regardless of operator preference, if succinylcholine is contraindicated, rocuronium should be used. Both the induction agent and the NMBA are given by IV push. RSI does not involve the slow administration of the induction agent, or a titration-to-end point approach sometimes used for induction of general anesthesia. The sedative agent and dose are selected with the intention of rapid IV administration of the drugs. Although rapid administration of the induction agent can increase the likelihood and severity of side effects, especially hypotension, the entire technique is predicated on rapid loss of consciousness, rapid neuromuscular blockade, and a brief period of apnea, typically without interposed assisted ventilation before intubation. Therefore, the induction agent is given as a rapid push, followed immediately by a rapid push of the NMBA. Within 10 to 20 seconds of the administration of the induction agent and NMBA, the patient will begin to lose consciousness, and respiration will decline, and then cease.

Positioning

After 20 to 30 seconds, the patient is unconscious, apneic, and becoming flaccid. If succinylcholine has been used as the NMBA, fasciculations will be observed during this time. It is crucial that the oxygen mask and nasal cannula used for preoxygenation remain in place to prevent the patient from acquiring even a partial breath of room air. Oxygen stores deplete rapidly if the patient is allowed to breath room air. At this point, the patient is positioned optimally for intubation, with consideration for cervical spine immobilization in trauma. The bed should be at sufficient height to comfortably perform laryngoscopy, although this is much more an issue for direct than for video laryngoscopy. The patient is transitioned fully to the head of the bed, if not done earlier, and, if there are no contraindications,

the head is elevated and extended. Some patients will be sufficiently compromised or at risk for critical desaturation during the brief period from drug administration to full relaxation as to require assisted ventilation continuously throughout the sequence to maintain oxygen saturations over 90%. Such patients, especially those with profound hypoxemia, are ventilated with bag and mask except when laryngoscopy is occurring. Patients will maintain high oxygen saturations longer if they receive oxygen at 5 to 15 L/min through nasal cannula throughout laryngoscopy. The highest nasal cannula flow rate the patient can tolerate while awake should be used. The flow rate can then be increased to as much as 15 L/min after the patient is unconscious.

Placement With Proof

At 45 to 60 seconds after the administration of either succinylcholine or rocuronium, test the patient's jaw for flaccidity and intubate. Strict attention to robust preoxygenation endows most patients with *minutes* of safe apnea time, allowing the intubation to be performed gently and carefully. Multiple attempts, if needed, are often possible without any need to provide additional oxygenation by bag and mask. Tube placement is confirmed as described in Chapter 15. End-tidal carbon dioxide ($ETCO_2$) detection is mandatory. A capnometer, such as a colorimetric $ETCO_2$ detector, is sufficient for this purpose. We recommend the use of continuous quantitative capnography, if available, as this provides ongoing information for postintubation management in addition to initial and ongoing verification of tube placement.

Postintubation Management

After placement is confirmed, the ETT is secured in place. Mechanical ventilation is initiated as described in Chapter 10. A chest radiograph should be obtained as soon as possible to assess pulmonary status and ensure that mainstem intubation has not occurred. Hypotension is common in the postintubation period and is often caused by diminished venous blood return as a result of the increased intrathoracic pressure that attends mechanical ventilation, exacerbated by the hemodynamic effects of the induction agent. Although this form of hypotension is often self-limited and

responds to IV fluids, persistent or profound hypotension may indicate a more ominous cause, such as tension pneumothorax or impending circulatory collapse. If significant hypotension is present, consider the management steps in **Table 20.1**.

TABLE 20.1 Hypotension in the Postintubation Period

Cause	Detection	Action
Pneumothorax	Increased peak inspiratory pressure (PIP), difficulty bagging, decreased breath sounds, and decreasing oxygen saturation	Immediate thoracostomy
Decreased venous return	Especially in patients with high PIPs secondary to high intrathoracic pressure or those with marginal hemodynamic status before intubation	Fluid bolus and treatment of airway resistance (bronchodilators); increase the inspiratory flow rate to allow increased expiratory time; try ↓ V_T, respiratory rate, or both if SpO_2 is adequate, and decrease the dose of sedation agent(s)
Induction agents	Other causes excluded	Fluid bolus and decrease the dose of sedation agent(s)
Cardiogenic	Usually in compromised patient; ECG; exclude other causes	Fluid bolus (caution), pressors, and decrease the dose of sedation agent(s)

Long-term sedation is generally indicated and is mandatory when long-term neuromuscular blockade is used. Emergency department (ED)-based research suggests that sedation is either not administered or given in inadequate doses in as many as 18% of patients after intubation using neuromuscular blockade. Long-term paralysis, however, is generally avoided, except when necessary for specific aspects of patient management. Use of a sedation scale, such as the Richmond Agitation Sedation Scale, helps guide decision-making regarding the necessity of neuromuscular blockade (**Box 20.3**). Sedation and analgesia are administered to reach the desired level, and neuromuscular blockade is used only if the patient then requires it for management. Use of a sedation scale prevents the use of neuromuscular blockade for patient control when the cause of the patient's agitation is inadequate sedation or analgesia. A sample sedation protocol is shown in **Figure 20.3**. Maintenance of intubation and mechanical

ventilation require both sedation and analgesia, and these can be titrated to patient response. Propofol has become the agent of choice for ongoing sedation in mechanically ventilated patients, especially for those with neurologic conditions. Propofol is preferable because it can be discontinued or decreased with rapid recovery of consciousness. Propofol infusion can be started at 25 to 50 µg/kg/min and titrated. An initial bolus of 0.5 to 1 mg/kg may be given if rapid sedation is desired. Analgesia is required, as above, because propofol is not an analgesic. Secondary sedation strategies might include midazolam 0.1 to 0.2 mg/kg, combined with an analgesic such as fentanyl 2 µg/kg, morphine 0.2 mg/kg, or hydromorphone (Dilaudid) 0.03 mg/kg. Fentanyl may be preferable because of its superior hemodynamic stability. When an NMBA is required, a full paralytic dose should be used (see Chapter 22). Sedation and analgesia are difficult to titrate when the patient is paralyzed, and “topping up” doses should be administered regularly, before physiologic stress (hypertension and tachycardia) is evident.

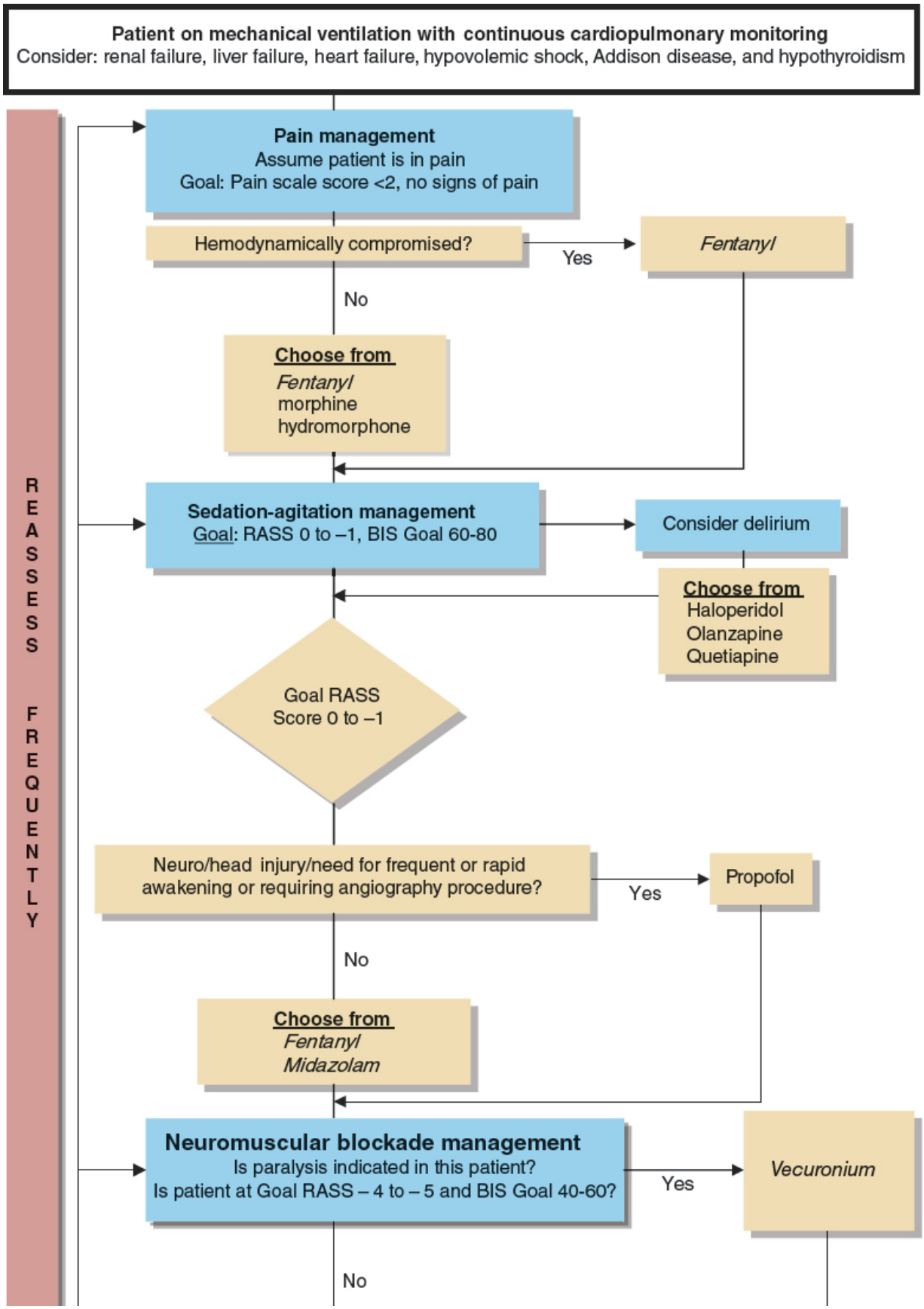
Patient on mechanical ventilation with continuous cardiopulmonary monitoring
Consider: renal failure, liver failure, heart failure, hypovolemic shock, Addison disease, and hypothyroidism
REASSESS FREQUENTLY
Pain management
Assume patient is in pain
Goal: Pain scale score <2, no signs of pain
Hemodynamically compromised?
Yes
Fentanyl
No
Choose from
Fentanyl
morphine
hydromorphone
Sedation-agitation management
Goal: RASS 0 to –1, BIS Goal 60-80
Consider delirium
Choose from
Haloperidol
Olanzapine
Quetiapine
Goal RASS
Score 0 to –1
Neuro/head injury/need for frequent or rapid awakening or requiring angiography procedure?
Yes
Propofol
No
Choose from
Fentanyl
Midazolam
Neuromuscular blockade management
Is paralysis indicated in this patient?
Is patient at Goal RASS – 4 to – 5 and BIS Goal 40-60?
Yes
Vecuronium
No

Figure 20.3: Postintubation management protocol using the RASS score. See also Box 20.3 for description of the Richmond Agitation Sedation Scale (RASS). BIS, Bispectral Index. (The protocol, adapted with permission, was developed for use at Brigham and Women's Hospital, Boston, MA.)

BOX 20.3 Richmond Agitation Sedation Scale

Score	Term	Description	
+ 4	Combative	Overtly combative, violent, and immediate danger to staff	
+ 3	Very agitated	Pulls or removes tube(s) or catheter(s) and is aggressive	
+ 2	Agitated	Frequent nonpurposeful movement and fights ventilator	
+ 1	Restless	Anxious but movements not aggressive and vigorous	
0	Alert and calm		
−1	Drowsy	Not fully alert but has sustained awakening (eye opening/eye contact) to *voice* (>10 sec)	Verbal stimulation
−2	Light sedation	Briefly awakens with eye contact to *voice* (<10 sec)	
−3	Moderate sedation	Movement or eye opening to *voice* (but no eye contact)	
−4	Deep sedation	No response to voice but movement or eye opening to *physical* stimulation	Physical stimulation
−5	Unarousable	No response to *voice* or *physical* stimulation	

Procedure for Richmond Agitation Sedation Scale Assessment

1. Observe patient.
   a. Patient is alert, restless, or agitated. **(score 0 to +4)**
2. If not alert, state patient's name and *say* to open eyes and look at speaker.
   b. Patient awakens with sustained eye opening and eye contact. **(score −1)**
   c. Patient awakens with eye opening and eye contact but not sustained. (**score −2**)
   d. Patient has any movement in response to voice but no eye contact. (**score −3**)

3. When no response to verbal stimulation, physically stimulate patient by shaking shoulder and/or rubbing sternum.
   e. Patient has any movement to physical stimulation. **(score −4)**
   f. Patient has no response to any stimulation. **(score −5)**

Adapted from Sessler CN, Gosnell M, Grap MJ, et al. The Richmond Agitation-Sedation Scale: validity and reliability in adult intensive care patients. Am J Respir Crit Care Med. 2002;166:1338-1344; and Ely EW, Truman B, Shintani A, et al. Monitoring sedation status over time in ICU patients: the reliability and validity of the Richmond Agitation Sedation Scale (RASS). JAMA. 2003;289:2983-2991.

Timing the Steps of RSI

Successful RSI requires a detailed knowledge of the sequence of steps to be taken and of the minimum time required for each step to achieve its purpose. The duration of time from preparation to administration of RSI medications is variable and depends on the clinical scenario. Although some patients may require an airway immediately, such as in a case of rapidly progressing anaphylaxis, some patients will have no immediate threat to oxygenation and ventilation but present with profound hypotension, and the clinician may invest additional time on fluid resuscitation and hemodynamic optimization before proceeding with RSI drugs. Preoxygenation requires at least 3 minutes for maximal effect. If necessary, in a cooperative patient, eight successive vital capacity breaths can accomplish equivalent preoxygenation in <30 seconds. The pharmacokinetics of the sedatives and neuromuscular blockers would suggest that a 45 to 60 second interval between administration of these agents and initiation of endotracheal intubation is optimal. Onset may be delayed if the patient's condition results in poor cardiac output because drug distribution will be impaired. In low-flow states, ensure that the highest recommended weight-based dose is used to compensate for impaired delivery. Thus, the entire sequence of RSI can be described as a series of timed steps. For the purposes of discussion, *time zero* is the time at which the sedative agent and NMBA are pushed. If the need for intubation is not immediate and standard preparatory steps can be taken, then the operator needs a minimum of 5 to 15 minutes to accomplish a safe and efficient team response with a defined rescue plan, sufficient preoxygenation, and physiologic optimization. As already mentioned, the timeline leading up to

administration of RSI drugs can vary greatly based on the urgency for tube placement and patient stability. A hypotensive blunt trauma patient with an open femur fracture and an unstable pelvis, but no immediate threat to the airway, may need 20 to 30 minutes in order to establish IV access and begin blood product resuscitation to optimize the safety of intubation. Therefore, although there are minimum time requirements for certain preintubation steps, preparation for RSI may take longer if a patient requires physiologic optimization prior to intubation or may be shortened if the intubation is highly emergent. The recommended sequence is shown in **Table 20.2**.

TABLE 20.2 Rapid Sequence Intubation

Time	Action (Seven Ps)
Zero minus 10+ min	**P**reparation: *Assemble all necessary equipment, drugs, etc.*
Zero minus 10+ min (at least 3 min)	**P**reoxygenation
Zero minus 10+ min	**P**hysiologic optimization
Zero	**P**aralysis with induction: *Administer induction agent by IV push, followed immediately by paralytic agent by IV push*
Zero plus 30 sec	**P**ositioning: *Position patient for optimal laryngoscopy; continue oxygen supplementation at 5-15 L/min by nasal cannula after apnea ensues*
Zero plus 45 sec	**P**lacement with proof: *Assess mandible for flaccidity; perform intubation; confirm placement*
Zero plus 1 min	**P**ostintubation management: *Long-term sedation with paralysis only if indicated*

An example of RSI performed for a generally healthy 40-year-old, 80-kg patient is shown in **Table 20.3**. Other examples of RSI for particular patient conditions are in the corresponding sections throughout this manual.

TABLE 20.3 RSI for Healthy 80-kg Patient

Time	Action (Seven Ps)
Zero minus 10+ min	**P**reparation
Zero minus 10+ min	**P**reoxygenation
Zero minus 10+ min	**P**hysiologic *optimization*: *None indicated*
Zero	**P**aralysis with induction: *Etomidate 24 mg IV push; succinylcholine 120 mg IV push*

Zero plus 20-30 sec	**P**ositioning: *Position patient for optimal laryngoscopy; continue oxygen supplementation at 5-15 L/min*
Zero plus 45 sec	**P**lacement with proof: *Confirm with $ETCO_2$, physical examination*
Zero plus 1 min	**P**ostintubation management: *Long-term sedation/paralysis as indicated*

Success Rates and Adverse Events

RSI has a very high overall success rate in the emergency department, approximately 99% in most modern series. The National Emergency Airway Registry (NEAR), an international multicenter study of >19 000 adult emergency department intubations, reported a first-attempt success of 85% when RSI was used. RSI success rates are higher than those for other emergency airway management methods. The ultimate success rate was 99.4% for all encounters. RSI was the principal approach, used in 85% of all first attempts. The NEAR investigators classify events related to intubation as follows:

- Immediate complications such as witnessed aspiration, broken teeth, airway trauma, and undetected esophageal intubation
- Technical problems such as mainstem intubation, cuff leak, and recognized esophageal intubation
- Physiologic alterations such as pneumothorax, pneumomediastinum, cardiac arrest, and dysrhythmia

This system allows witnessed complications to be identified and all adverse events to be captured but avoids the misattribution of various technical problems (eg, recognized esophageal intubation or tube cuff failure) or physiologic alterations (eg, cardiac arrest in a patient who was *in extremis* before intubation was undertaken and that may or may not be attributable to the intubation) as complications. In the NEAR registry, the peri-intubation event rate is low, approximately 12% of patients, with the most common being recognized esophageal intubation (3.3%), followed by hypotension (1.6%). Hypotension and alterations in heart rate can result from the pharmacologic agents used or from stimulation of the larynx with resultant autonomic reflexes. Other studies have reported consistent results. The most catastrophic complication of RSI is unrecognized esophageal

intubation, which is rare in the emergency department but underscores the importance of confirming tube placement by $ETCO_2$ detection. It is incumbent on the person who performs RSI to be able to maintain patient oxygenation, ideally by establishing an airway and maintaining mechanical ventilation. This process may require a surgical airway as the final rescue from failed oral intubation attempts (see Chapter 5). Aspiration of gastric contents can occur but is uncommon. Overall, the true complication rate of RSI in the emergency department is low, and the success rate is exceedingly high, especially when one considers the serious nature of the illnesses for which patients are intubated, as well as the limited time and information available to the clinician performing the intubation.

Delayed Sequence Intubation

When a patient is persistently hypoxemic or at risk for precipitous oxyhemoglobin desaturation and is unable to cooperate with providers in achieving oxygenation, it may be appropriate to temporarily pause during the intubation sequence to focus on maximizing preoxygenation. This approach has been called delayed sequence intubation or DSI and is predicated on failure of the ability to preoxygenate using usual methods. The fundamental difference between DSI and what we describe as physiologic optimization is that, for the latter, all measures are taken before an induction agent is given. With the DSI technique, an induction agent is given first, in hopes of facilitating oxygenation of an uncooperative or agitated patient. The technique involves administration of a dissociative dose of ketamine (1 mg/kg IV), followed by several minutes of oxygenation using a non-rebreather face mask or pressure support mask ventilation (such as Bi-PAP or continuous positive airway pressure). When oxygenation is felt to be optimal, the operator pushes the NMBA and intubates as for RSI. One case series of approximately 60 ED and ICU patients showed a significant improvement in pre- and post-DSI saturations using this strategy. Additionally, no desaturation events were reported, even in high-risk patients. Although this process may have promise, it has not been validated in general ED environments or studies of sufficient size and has not been compared with conventional RSI for outcomes, including complications. Although it is reasonable to use this approach in selected

cases, we prefer undertaking oxygenation as part of patient optimization whenever possible, then performing the RSI swiftly, as outlined previously.

EVIDENCE

What is the optimal method for preoxygenation?

Standard preoxygenation has traditionally been achieved by 3 minutes of tidal volume breathing of 100% oxygen or eight vital capacity breaths. Preoxygenation of normally sized healthy patients can produce an average of 6 to 8 minutes of apnea time before desaturation to 90% occurs, but the times are much less (as little as 2-3 minutes) in patients with cardiovascular disease, obese patients, and small children. Preoxygenation with flush-flow rate oxygen should be done whenever possible because oxygenation is superior to that accomplished by face mask with 15 L/min oxygen flow. In a randomized trial of healthy volunteers, oxygenation with an NRB mask at flush rate (50 L/min) resulted in the highest (86%) single-breath fraction of expired oxygen (FeO_2), a surrogate marker for nitrogen wash-out. The NRB mask at 15 L/min performed poorly, achieving an FeO_2 of only 54%.[1] A follow-up study by the same investigators showed that an NRB mask with flush-rate oxygen was noninferior to bag-valve-mask using similar flow rates, whether or not bag assist was performed. Bag-mask devices performed poorly owing to significant mask leak.[2] Flush-rate preoxygenation requires no additional equipment, personnel, or monitoring than prior techniques yet outperforms other ambient pressure modalities. *Our recommendation is that flush-rate preoxygenation via NRB mask is the default starting technique for all emergency RSIs with the patient in either an upright or reverse Trendelenburg position*. This is particularly important for obese patients, for whom positioning is as crucial for creation of an oxygen reservoir as the oxygen supply. A recent meta-analysis of 14 studies demonstrates that apneic oxygenation (continued high-flow oxygen administration by nasal cannula during the apneic period of intubation) slows the rate of desaturation during airway management. Apneic oxygenation was associated with decreased hypoxemia (odds ratio [OR] 0.66; 95% confidence interval [95% CI] 0.52-0.84) and an increased first-pass success rate (OR 1.59; 95% CI 1.04-2.44).[3] In obese patients, apneic oxygenation may be even more important because of the rapid desaturation

these patients otherwise exhibit. When obese patients receive continuous oxygen at 5 L/min during the apneic phase of intubation, desaturation is delayed to about 5.25 minutes versus 3.75 minutes for a nonoxygenated comparison group, and 8/15 oxygenated patients versus 1/15 nonoxygenated patients maintained oxyhemoglobin saturation of 95% or higher for 6 minutes.[4] Bi-PAP or HFNO with PEEP is required for patients with suboptimal oxygen saturations (<94%) despite flush-flow ambient pressure supplemental oxygen. This indicates a high-shunt fraction and the need for alveolar recruitment. Both are effective, and evidence, to date, has not shown one modality to have clear superiority over the other. In a recent multicenter trial, in 322 ICU patients being intubated for acute hypoxemic respiratory failure, randomized to either noninvasive positive-pressure ventilation or high-flow nasal cannula for preoxygenation, there was no difference in the rate of severe peri-intubation hypoxemia between the two groups (23% vs 27%, respectively, absolute difference 4.2%, 95% CI −13.7 to 5.5; $P = .39$).[5] For practical purposes, these two modalities should be considered to have near clinical equipoise, and either can be used. The advantage of HFNO is that it can be continued during oral tracheal intubation. The relatively high rate of hypoxemia in this study also emphasizes the importance of carefully performing interposed positive-pressure ventilation in patients with hypoxemic respiratory failure and high-shunt fractions (ie, acute respiratory distress syndrome [ARDS]) because alveolar de-recruitment happens immediately after positive pressure is removed.

What is the evidence for Delayed Sequence Intubation?

The term *delayed sequence intubation* is meant to describe the act of sedating patients with ketamine at a dose of 1 mg/kg IV for the purposes of facilitating preoxygenation by either face mask or Bi-PAP. One case series of both ICU and ED patients showed an average improvement of 9% in oxygen saturation from a pre-DSI saturation of 90% to a post-DSI saturation of 99%. There were no desaturation events, even in high-risk patients.[6] This study suggests this approach is successful in ICU and high-intensity EDs with specially trained personnel who are experienced using ketamine in this way and have the staff to closely monitor the patient after ketamine is administered. There are insufficient data to recommend this

technique beyond very limited use by highly experienced personnel in high-intensity ED and ICU settings.

Should interposed bag-mask ventilation be performed routinely during RSI?

RSI has historically been taught as a nonbagging procedure, except for cases where patients were persistently hypoxic despite preoxygenation. However, there may be patients, who have normal SaO_2 during preoxygenation but, owing to illness, body habitus, or intrinsic lung disease, are at high risk for critical oxyhemoglobin desaturation in the time window from drug administration to the creation of intubating conditions that allow for laryngoscopy and intubation. In a recent multicenter ICU study, 401 patients intubated for hypoxemic respiratory failure were randomized to either interposed bag-mask ventilation or NRB mask (usual care) during airway management. Patients in the bag-mask ventilation group had significantly lower rates of severe hypoxemia (defined as SpO_2 or SaO_2 < 80%), 11% versus 23%, and higher nadirs of oxygen desaturation without evidence of increased aspiration. Although this was a significant finding, these results are hard to extrapolate to emergency department patients. In this study, patients were more likely to be fasted because they were inpatients being managed in an intensive care unit. Additionally, those deemed to be at high risk for aspiration were excluded from the study. There was also no standardized preoxygenation strategy, and it is possible that interposed bag-mask ventilation simply rescued poor preoxygenation techniques. The investigators did not compare bag-mask ventilation with high-flow nasal oxygenation throughout and after conventional preoxygenation. At the same time, the differences were stark and study methodology sound. As a result, we recommend that if the clinician deems the risk of critical, rapid desaturation outweighs the risk of aspiration, then gentle, controlled interposed bag-mask ventilation should be performed in the time between RSI drug administration and laryngoscopy.[7]

What are the hemodynamic consequences of RSI?

The combination of acute illness, hemorrhage, dehydration, sepsis, and the vasodilatory effects of induction agents makes peri-intubation hypotension a common event. One retrospective review of 336 emergency department

intubations found that significant peri-intubation hypotension occurred 23% of the time. Patients with peri-intubation hypotension were more likely elderly, suffering from chronic obstructive pulmonary disease, or had an elevated shock index (SI) on arrival and, not surprisingly, went on to have significantly higher in-hospital mortality.[8] A recent analysis of more than 15 000 medical intubations from the NEAR revealed that the rate of peri-intubation cardiac arrest was 1.0%. Patients at highest risk were those with preintubation shock (aOR 6.2; 95% CI 4.5-8.4) and hypoxia (aOR 3.1; 95% CI 2.0-4.8).[9] A before and after ICU study showed that a strategy using effective preloading, cardio-stable drug selection, and early use of vasopressors resulted in significantly lower rates of cardiac arrest, refractory shock, and critical hypoxemia.[10] These studies form the current basis for our recommendation to maximize patient physiology prior to RSI.

Is RSI superior to intubation with sedation alone?

This is also discussed in the evidence section for Chapter 22. The most powerful evidence supporting the use of an NMBA in addition to an induction agent comes from dosing studies of NMBAs, of which there are many. The results are uniformly the same. Intubation is more successful because of better intubating conditions when an NMBA is used compared with when an induction agent alone is used. Results from the NEAR III report of 17 583 adult intubations showed that RSI yielded higher first-attempt success (85%) compared with intubations facilitated by sedatives alone (76%).[11] Although the number of advocates for ketamine-only intubations has been on the rise, a recent analysis from NEAR revealed that ketamine-only intubations were performed in only 80/12 511 encounters (0.6%) and were associated with lower unadjusted first-attempt success rates compared with RSI (61% vs 90%, respectively). The rate of at least one peri-intubation adverse event was also higher (32% vs 14%).[12]

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CHAPTER 21

Sedative-Induction Agents

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INTRODUCTION

Agents used to sedate, or "induce," patients for intubation during rapid sequence intubation (RSI) are properly called sedative-induction agents because induction of general anesthesia is at the extreme of the spectrum of their sedative actions. In this chapter, we refer to this family of drugs as "induction agents." The ideal induction agent would smoothly and quickly render the patient unconscious, unresponsive, and amnestic in one arm/heart/brain circulation time. It would also provide analgesia, maintain stable cerebral perfusion pressure (CPP) and cardiovascular hemodynamics, be immediately reversible, and have few, if any, adverse physiologic effects. Unfortunately, such an induction agent does not exist. Most induction agents meet the first criterion because they are highly lipophilic and so have a rapid onset within 15 to 30 seconds of intravenous (IV) administration. Their clinical effects are also terminated quickly as the drug rapidly redistributes to less-well-perfused tissues. However, all induction agents have the potential to cause dose-dependent myocardial depression and subsequent hypotension. These effects depend on the particular drug; the patient's underlying physiologic condition; and the dose, concentration, and speed of injection of the drug. The faster the drug is administered IV and the larger the concentration of drug that saturates organs with the greatest blood flow (ie, brain and heart), the more pronounced its effect. Because RSI requires rapid administration of a precalculated dose of an induction agent, the choice of drug and the dose must be individualized to capitalize on desired effects, while minimizing those that might adversely affect the patient. Some patients are so unstable, despite preinduction optimization,

that the primary goal is to produce amnesia rather than anesthesia because to produce the latter might lead to severe hypotension and organ hypoperfusion.

The most used emergency induction agent is etomidate (Amidate), which is popular because of its rapid onset of action, relative hemodynamic stability, and widespread availability. Recent registry data suggest ketamine (Ketalar) and propofol (Diprivan) are the next two most commonly used induction agents. Midazolam is available for use as an induction agent but should be considered a distant fourth option and used only if other agents are unavailable. It is less reliable in inducing anesthesia, has a slower onset of action, and is more likely to produce hypotension than either etomidate or ketamine at full induction dose. The ultra-short-acting barbiturates such as methohexital (Brevital) and the ultra-short-acting opioids such as remifentanil (Ultiva) are rare in the ED and will not be discussed in further detail in this chapter. The relatively selective, α_2-adrenergic-agonist dexmedetomidine is not used as an RSI induction agent because it is not administered as a rapid bolus by IV push but may have a role during awake airway evaluations.

General anesthetic agents act through two principal mechanisms: (i) an increase in inhibition through activity at gamma-aminobutyric acid “A” (GABA) receptors (eg, benzodiazepines, barbiturates, propofol, etomidate, isoflurane, enflurane, and halothane), and (ii) a decreased excitation through *N*-methyl-D-aspartate (NMDA) receptors (eg, ketamine, nitrous oxide, and xenon).

The IV induction agents discussed in this chapter share important pharmacokinetic characteristics. Induction agents are highly lipophilic, and because the brain is a highly perfused, lipid-dense organ, a standard induction dose of each agent in a euvolemic, normotensive patient will produce unconsciousness within 30 seconds. The blood-brain barrier is freely permeable to medications used to induce anesthesia. The observed clinical duration of each drug is measured in minutes because of the drugs’ distribution half-life ($t_{1/2}\alpha$), characterized by distribution of the drug from the central circulation to well-perfused tissues, such as the brain. Drug redistribution from brain to fat and muscle terminates its central nervous system (CNS) effects. The elimination half-life ($t_{1/2}\beta$, usually measured in

hours) is characterized by each drug's reentry from fat and lean muscle into plasma down a concentration gradient leading to hepatic metabolism and renal excretion. Generally, it requires four to five elimination half-lives to completely clear the drug from the body.

The dosing of induction agents in nonobese adults should be based on ideal body weight (IBW) in kilograms; however, in clinical practice, the total body weight (TBW or actual body weight) is a close enough approximation to IBW for the purposes of dosing these agents. The situation, however, is more complicated for morbidly obese patients. The high lipophilicity of the induction agents combined with the increased volume of distribution (V_d) of these drugs in obesity argues for TBW dosing. Opposing this, however, is the significant cardiovascular depression that would occur if such a large quantity of drug is injected as a single bolus. Balancing these two considerations, and given the paucity of actual pharmacokinetic studies in obese patients, the best approach is to use lean body weight (LBW) for dosing of most induction agents, in morbidly obese patients. Decrease to IBW if the patient is hemodynamically compromised, or for drugs with significant hemodynamic depression, such as propofol. LBW is obtained by adding 0.3 of the patient's excess weight (TBW minus IBW) to the IBW, and using the sum as the dosing weight. More details on drug dosing for obese patients are provided in Chapter 43.

Aging affects the pharmacokinetics of induction agents. In elderly patients, lean body mass and total body water decrease, whereas total body fat increases, resulting in an increased volume of distribution, an increase in $t_{1/2}\beta$, and an increased duration of drug effect. In addition, the elderly are more sensitive to the hemodynamic and respiratory depressant effects of these agents, and the induction doses should be reduced to approximately one-half of the dose used in their healthy, younger counterparts.

ETOMIDATE

Etomidate (Amidate)				
Usual Emergency Induction Dose (mg/kg)	**Onset (sec)**	**$t_{1/2}\alpha$ (min)**	**Duration (min)**	**$t_{1/2}\beta$ (hr)**
0.3	15–45	2–4	3–12	2–5

Clinical Pharmacology

Etomidate is an imidazole derivative that is primarily a hypnotic and has no analgesic activity. Etomidate is the most hemodynamically stable of the currently available induction agents. It exerts its effect by enhancing GABA activity at the GABA-receptor complex. GABA receptors moderate the activity of inhibitory chloride channels, thus making neurons less excitable. Etomidate attenuates the underlying elevated intracranial pressure (ICP) by decreasing cerebral blood flow (CBF) and cerebral metabolic rate for oxygen ($CMRO_2$). Its hemodynamic stability preserves CPP. Etomidate is cerebroprotective and, along with its hemodynamic stability and favorable CNS effects, make it an excellent choice for patients with elevated ICP.

Etomidate does not release histamine and is safe for use in patients with reactive airway disease. However, it lacks the direct bronchodilatory properties of ketamine or propofol, which may be preferable agents in these patients.

Indications and Contraindications

Etomidate has become the induction agent of choice for most emergent RSIs because of its reliable and rapid onset, hemodynamic neutrality, its positive effect on $CMRO_2$ and CPP, and its rapid recovery. As with any induction agent, dosing should be reduced in hemodynamically compromised patients. Etomidate is a U.S. Food and Drug Administration (FDA) pregnancy category C drug. Etomidate is not FDA approved for use in children, but many series report safe and effective use in pediatric patients.

Dosage and Clinical Use

In euvolemic and hemodynamically stable patients, the normal induction dose of etomidate is 0.3 mg/kg IV push. In hemodynamically compromised patients, the dose should be reduced commensurate with the patient's clinical status; reduction to 0.15 mg/kg is sufficient. In morbidly obese patients, the induction dose should be based on LBW, as discussed in the previous section.

Adverse Effects

Pain on injection is common because of the diluent (propylene glycol) and can be mitigated by having a fast-flowing IV solution running in a large vein. Myoclonic movement during induction is common and has been confused with seizure activity. It is of no clinical consequence and generally terminates promptly as the neuromuscular blocking agent takes effect.

The most significant and controversial side effect of etomidate is its temporary and reversible inhibition of adrenal cortisol production by blockade of 11-β-hydroxylase, which decreases both serum cortisol and aldosterone levels. This side effect occurs both with continuous infusions of etomidate in the ICU setting and with a single-dose injection used for emergency RSI but is much more significant when used as an infusion and, therefore, is no longer advocated for this purpose. The risks and benefits of the use of etomidate in patients with sepsis are discussed in detail in the "Evidence" section at the end of the chapter.

KETAMINE

Ketamine (Ketalar)				
Usual Emergency Induction Dose (mg/kg)	**Onset (sec)**	**$t_{1/2}\alpha$ (min)**	**Duration (min)**	**$t_{1/2}\beta$ (hr)**
1.5	45-60	11-17	10-20	2-3

Clinical Pharmacology

Ketamine is a phencyclidine derivative that provides significant analgesia, anesthesia, and amnesia, with minimal effect on respiratory drive. The amnestic effect is not as pronounced as that seen with the benzodiazepines. Ketamine is believed to interact with NMDA receptors, promoting neuroinhibition and subsequent anesthesia. Action on NMDA receptors in spinal cord dorsal horn neurons are thought to account for its analgesic effect. Ketamine stimulates the release of catecholamines, activating the sympathetic nervous system, and augmenting heart rate and blood pressure (BP) in those patients who are not catecholamine depleted secondary to the demands of their underlying disease. Furthermore, increases in mean arterial pressure (MAP) may offset any rise in ICP, resulting in a relatively

stable CPP. In addition to its catecholamine-releasing effect, ketamine directly relaxes bronchial smooth muscle, producing bronchodilation. Ketamine is primarily metabolized in the liver, producing one active metabolite, norketamine, which is metabolized and excreted in the urine.

Indications and Contraindications

Ketamine is commonly used as the induction agent for patients intubated for severe status asthmaticus. It is also an excellent induction agent for patients who are hypovolemic, hypotensive, or newly hemodynamically unstable (ie, a young trauma victim with bleeding and hypotension). Ketamine should be used with caution in older patients who present with critical illness of longer duration and are at risk for catecholamine depletion. In this setting, ketamine's myocardial depressant effect may prevail and result in worsening hemodynamics or circulatory collapse. In normotensive or hypertensive patients with ischemic heart disease, catecholamine release may adversely increase myocardial oxygen demand. Ketamine's preservation of upper airway reflexes makes it appealing for awake laryngoscopy and intubation in the difficult airway patient where the dose is titrated to effect. Concern has been raised regarding ketamine's effect on ICP in the past, especially in the head-injured patient. Although it has been linked to mild increases in ICP, ketamine also increases MAP and therefore CPP. Ketamine has been increasingly used in head-injured patients, and no study to date has identified an increase in mortality when used in the head-injured patient. Ketamine is classified as pregnancy category C.

Dosage and Clinical Use

The induction dose of ketamine for RSI is 1.5 mg/kg IV. In patients who are catecholamine depleted, doses more than 1.5 mg/kg IV may cause myocardial depression and exacerbate hypotension. Because of its generalized stimulating effects, ketamine enhances laryngeal reflexes and can increase pharyngeal and bronchial secretions. These effects may uncommonly precipitate laryngospasm and may interfere with upper airway examination during awake intubation but are generally not an issue during RSI. Atropine 0.01 mg/kg IV or glycopyrrolate (Robinul) 0.005 mg/kg IV

may be administered 15 minutes before ketamine to promote a drying effect for awake intubation, when feasible. Ketamine is available in three separate concentrations: 10, 50, and 100 mg/mL. Care should be taken to verify which concentration is utilized during RSI to avoid inadvertent over- or underdosing.

Adverse Effects

Hallucinations may occur on emergence from ketamine and are more common in adults than in children. Such emergence reactions occur infrequently in the emergency department as most patients are subsequently sedated with either a benzodiazepine or propofol, after the airway has been secured.

PROPOFOL

Propofol (Diprivan)				
Usual Emergency Induction Dose (mg/kg)	**Onset (sec)**	**$t_{1/2}\alpha$ (min)**	**Duration (min)**	**$t_{1/2}\beta$ (min)**
1.5	15-45	1-3	5-10	1-3

Clinical Pharmacology

Propofol is an alkylphenol derivative (ie, an alcohol) with hypnotic properties. It is highly lipid soluble. Propofol enhances GABA activity at the GABA-receptor complex and decreases $CMRO_2$ and ICP. Propofol does not cause histamine release, but it does cause a reduction in BP through vasodilation and direct myocardial depression. The ensuing hypotension and resultant decrease in CPP may be detrimental in a compromised patient. The manufacturer recommends that rapid bolus dosing (either single or repeated) be avoided in patients who are elderly, debilitated, or American Society of Anesthesiologists Class III or IV in order to minimize undesirable cardiovascular depression, including hypotension. It must be used cautiously for emergency RSI in hemodynamically unstable patients.

Indications and Contraindications

Propofol is an excellent induction agent in the hypertensive patient being intubated for a neurovascular emergency. The potential for hypotension, however, limits its use as the primary induction agent in emergent RSI, a role reserved for etomidate. There are no absolute contraindications to its use. Propofol is delivered as an emulsion in soybean oil and lecithin; patients who are allergic to eggs generally react to the ovalbumin and not to lecithin, so propofol is not contraindicated in patients with egg allergy. Propofol is a pregnancy category B drug and has become the induction agent of choice in pregnant patients.

Dosage and Clinical Use

The induction dose of propofol is 1.5 mg/kg IV in a euvolemic, normotensive patient. Because of its predictable tendency to reduce mean arterial BP, doses are reduced by one-third to one-half when propofol must be given as the induction agent for emergency RSI in compromised or elderly patients.

Adverse Effects

Propofol causes pain on injection, which can be attenuated by injecting the medication through a rapidly running IV in a large vein (eg, antecubital). Premedication of the vein with lidocaine (2-3 mL of 1% lidocaine) will also minimize the pain of injection. Propofol and lidocaine are compatible in the same syringe and can be mixed in a 10:1 ratio (10 mL of propofol to 1 mL of 1% lidocaine). Propofol can cause mild clonus, and venous thrombophlebitis at the injection site has been reported.

BENZODIAZEPINES

Short-Acting Benzodiazepines: Midazolam (Versed)				
Usual Emergency Induction Dose (mg/kg)	**Onset (sec)**	**$t_{1/2}\alpha$ (min)**	**Duration (min)**	**$t_{1/2}\beta$ (hr)**
0.2-0.3	60-90	7-15	15-30	2-6

Clinical Pharmacology

Benzodiazepines bind to a drug-specific receptor of the GABA complex and act to increase the frequency with which inhibitory chloride channels open. This results in CNS depression manifested by amnesia, anxiolysis, muscle relaxation, sedation, anticonvulsant effects, and hypnosis. Although the benzodiazepines generally have similar pharmacologic profiles, they differ in selectivity, making their clinical usefulness variable. The benzodiazepines have potent, dose-related amnestic properties, perhaps their greatest asset for emergency indications. However, midazolam's time to clinical effectiveness is much longer than for any of the other commonly used induction agent. When IV midazolam is given as an anesthetic induction agent, onset occurs in ~ 1.5 minutes when opioid premedication has been used and in 2 to 2.5 minutes without opioid premedication. Its pharmacokinetic attributes make it a poor induction agent, and it cannot be recommended for this purpose unless other options are unavailable. Midazolam has one significant active metabolite, 1-hydroxy-midazolam, which may contribute to its pharmacologic activity. Clearance of midazolam is reduced in association with old age, congestive heart failure, and liver disease. The elimination half-life of midazolam ($t_{1/2}\beta$) may be prolonged in renal impairment. The benzodiazepines do not release histamine, and allergic reactions are very rare.

Indications and Contraindications

The primary indications for benzodiazepines are to promote amnesia and sedation. In this regard, the benzodiazepines are unparalleled. Midazolam's primary use in the emergency department and elsewhere in the hospital is for procedural sedation.

Because of its dose-related reduction in systemic vascular resistance and direct myocardial depression, dosage must be adjusted in volume-depleted or hemodynamically compromised patients. The correct induction dose of midazolam, 0.3 mg/kg, is rarely used. Even at this dose, midazolam is a poor induction agent for emergent RSI because of delay in onset of action and adverse hemodynamic effects and should be chosen only if other agents are not available. All benzodiazepines are FDA pregnancy category D.

Dosage and Clinical Use

Midazolam is rarely used as an induction agent in the operating room, and we do not recommend its use for emergent RSI. Even in the correct induction dose for hemodynamically stable patients of 0.3 mg/kg IV push, the onset is slow, and so the drug is not suited for emergency applications. Midazolam should be reserved for sedative applications and used in emergency RSI only as a last resort.

Adverse Effects

Except for midazolam, the benzodiazepines are insoluble in water and are usually in solution in propylene glycol. Unless injected into a large vein, pain and venous irritation on injection can be significant.

EVIDENCE

Is etomidate safe to use in septic patients?

More than 15 years after critical care physicians were urged to abandon the use of etomidate, debate continues about the potential risks of etomidate, alternative agents, and overall mortality, especially in patients presenting with sepsis.[1–6] Much of the published literature is from retrospective data with significant confounding, and few patients have been enrolled in randomized clinical trials.[7] An extensive Cochrane review in 2015 demonstrated no conclusive evidence that single-dose etomidate for airway management increases mortality or health care resource utilization.[8] Any replacement for etomidate must have cardiovascular stability, a reliable onset of action, and simple dosing.

Which induction agents are the most hemodynamically stable when used for RSI in the unstable patient?

Although virtually all induction agents *could be used* for RSI, not all are appropriate. First attempt success is important, and we want to avoid both patient awareness and hemodynamic compromise.[9] Reduced-dose etomidate or ketamine will be the safest options for RSI in a patient with hemodynamic compromise.[10] Etomidate results in the least variation in BP and heart rate when used for rapid induction of anesthesia and should be considered the default induction agent for emergency airway management.[11,12] Ketamine also offers several advantages as an induction

agent in hemodynamically compromised patients. Clinical experience and evidence support the safe use of ketamine for RSI in most patients. Two recently published analyses from a large intubation registry observed that ketamine was associated with higher rates of both postinduction hypotension and the need for pressor agent use, particularly in patients with sepsis.[13,14] Ketamine should be used with caution in vulnerable hypotensive patients at risk for catecholamine depletion.[13] In this setting, etomidate is preferred.

What is the risk of ketamine in the brain-injured patient?

Ketamine has been noted to increase ICP through increased CBF and excitatory effects on neurons. Following brain injury, there is a loss of cerebral autoregulation, and CBF is largely dependent on CPP, which in turn is largely dependent on MAP. Consequently, agents such as etomidate and ketamine that maintain MAP will maintain CBF. This is particularly true in patients with polytrauma where traumatic brain injury and shock may coexist.[15] The dangers of hypotension on the injured brain are well known, and avoiding hypotension in traumatic brain injury is a priority.[16] In addition to the neuroprotective effects of maintaining CBF through CPP, ketamine has also been found to have other neuroprotective properties.[17] In the last few years, increasing clinical evidence of the safety of ketamine in brain-injured patients has emerged, and it is becoming increasingly clear that ketamine is not dangerous in brain-injured patients.[15,16,18] If the brain-injured patient is also hypotensive, then ketamine is an excellent choice.

Is ketofol an appropriate agent for RSI?

Ketofol, a 1:1 admixture of ketamine and propofol, has gained popularity as a combination agent for procedural sedation. The practitioner gives a half-dose of each of the medications, with the sum of both causing a similar level of sedation as either alone at full dose. Commonly used during procedural sedation, Ketofol has limited evidence as an induction agent, especially in hemodynamically compromised patients.[19,20]

What is the propofol infusion syndrome?

Propofol infusion syndrome is a rare condition, with an unclear mechanism, that was recognized initially in pediatric patients but subsequently in

patients of all ages. The clinical syndrome is nonspecific and includes metabolic acidosis, rhabdomyolysis, hemodynamic instability, and multisystem organ failure. Mortality is as high as 50% in adult and pediatric patients. Propofol infusion syndrome typically occurs after high doses (>5 mg/kg/hr) or infusions of long duration (48 hours) and is unlikely to be seen in the ED environment.[21] Protocols avoiding propofol as a sedative agent are common in some patient populations: patients with large burns and pediatric populations. Success in treating propofol infusion syndrome depends on early recognition, cessation of propofol infusions, and supportive care including renal replacement therapy.

How should sedative agents be dosed in the postintubation period?

Sedation and analgesia must be addressed immediately following the use of RSI.[22] Sedation is particularly important if a long-acting neuromuscular blocker such as rocuronium has been used for RSI or the patient is at risk for being awake and paralyzed.[23–25] In general, agents for sedation following intubation should be minimally hemodynamically active and ideally provide amnesia, sedation, and analgesia. As for induction medications, no perfect agent exists. Sedative dosing is more forgiving than induction dosing, and other agents can be considered. For example, an infusion of dexmedetomidine provided analgesia, sedation, and amnesia with minimal clinically important hemodynamic changes in intubated and unintubated ED patients.[26] Propofol provides exceptional sedation and amnesia but lacks analgesic properties. A trial comparing light sedation protocols of dexmedetomidine or propofol in ventilated critical care patients did not show substantial differences between the agents.[27] Dexmedetomidine, ketamine, and propofol are preferentially administered as infusions. Over the last 20 years, analgesic and sedative strategies in intensive care have changed dramatically.[28] Although benzodiazepine infusions were commonly used as sedatives, they are a modifiable risk factor for the development of ICU delirium and are no longer recommended as a primary sedative.[29]

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CHAPTER 22

Neuromuscular Blocking Agents

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INTRODUCTION

Neuromuscular blockade is the cornerstone of rapid sequence intubation (RSI), optimizing conditions for tracheal intubation whereas minimizing the risks of aspiration or other adverse physiologic events. Neuromuscular blocking agents (NMBAs) do not provide analgesia, sedation, or amnesia. As a result, they are paired with a sedative-induction agent for RSI. Similarly, appropriate sedation is essential when maintaining neuromuscular blockade postintubation.

Cholinergic nicotinic receptors on the postjunctional membrane of the motor endplate play the primary role in stimulating muscular contraction. Under normal circumstances, the presynaptic neuron synthesizes acetylcholine (ACH) and stores it in small packages (vesicles). Nerve stimulation results in these vesicles migrating to the prejunctional nerve surface, rupturing and discharging ACH into the synaptic cleft of the motor endplate. The ACH attaches to the nicotinic receptors, promoting depolarization, which culminates in a muscle cell action potential and muscular contraction. As the ACH diffuses away from the receptor, most of the neurotransmitter is hydrolyzed by acetylcholinesterase (ACHE). The remainder undergoes reuptake by the prejunctional neuron.

NMBAs are either agonists (“depolarizers” of the motor endplate) or antagonists (competitive agents, also known as “nondepolarizers”). Agonists work by persistent depolarization of the endplate, exhausting the ability of the receptor to respond. Antagonists, on the other hand, attach to

the receptors and competitively block access of ACH to the receptor while attached. Because they are in competition with ACH for the motor endplate, antagonists can be displaced from the endplate by increasing concentrations of ACH, the end result of reversal agents (cholinesterase inhibitors such as neostigmine, edrophonium, and pyridostigmine) that inhibit ACHE and allow ACH to accumulate and reverse the block. The ideal muscle relaxant to facilitate RSI would have a rapid onset of action, rendering the patient paralyzed within seconds; a short duration of action, returning the patient's normal protective reflexes within 3 to 4 minutes; no significant adverse side effects; and metabolism and excretion independent of liver and kidney function.

SUCCINYLCHOLINE

Depolarizing (Noncompetitive) NMBA: Succinylcholine

Intubating Dose (mg/kg)	Onset (sec)	$t_{1/2}\alpha$ (min)	Duration (min)	$t_{1/2}\beta$ (hr)	Pregnancy Category
1.5	45	<1	6-10	2-5	C

Succinylcholine (SCh) comes closest to meeting the desirable goals listed in the previous section. Rocuronium's popularity is increasing possibly as a result of the adverse effects of SCh and, in pediatric patients, the specter of hyperkalemia from administering SCh to a child with an undiagnosed degenerative neuromuscular disorder. Recent registry data suggest that SCh and rocuronium are used in about the same frequency in RSI.

Clinical Pharmacology

SCh is comprised of two molecules of ACH linked by an ester bridge and, as such, is chemically similar to ACH. It stimulates all nicotinic and muscarinic cholinergic receptors of the sympathetic and parasympathetic nervous system to varying degrees, not just those at the neuromuscular junction. For example, stimulation of cardiac muscarinic receptors can cause bradycardia, especially when repeated doses are given to small children. Although SCh can be a negative inotrope, this effect is so minimal

as to have no clinical relevance. SCh causes the release of trace amounts of histamine, but this effect is also not clinically significant. Initially, SCh depolarization manifests as fasciculations, but this is followed rapidly by complete motor paralysis. The onset, activity, and duration of action of SCh are independent of the activity of ACHE and instead depend on rapid hydrolysis by pseudocholinesterase (PCHE), an enzyme of the liver and plasma that is not present at the neuromuscular junction, before excretion in the urine. Therefore, diffusion away from the neuromuscular junction motor endplate and back into the vascular compartment is ultimately responsible for SCh metabolism. This extremely important pharmacologic concept explains why only a fraction of the initial intravenous (IV) dose of SCh ever reaches the motor endplate to promote paralysis. As a result, larger, rather than smaller, doses of SCh are used for emergency RSI. Incomplete paralysis may jeopardize the patient by compromising respiration while failing to provide adequate relaxation to facilitate tracheal intubation.

Succinylmonocholine, the initial metabolite of SCh, sensitizes the cardiac muscarinic receptors in the sinus node to repeat doses of SCh, which may cause bradycardia that is responsive to atropine. As a result, providers should be ready to treat significant bradycardia if repeat doses of SCh are required; however, there is no evidence that the prophylactic atropine is needed before a second dose. At room temperature, SCh retains 90% of its activity for up to 3 months. Refrigeration mitigates this degradation. Therefore, if SCh is stored at room temperature, it should be dated, and stock should be rotated regularly.

Indications and Contraindications

SCh is frequently used as an NMBA for emergency RSI because of its rapid onset and relatively brief duration of action. A personal or family history of malignant hyperthermia (MH) is an absolute contraindication to the use of SCh. Inherited disorders that lead to abnormal or insufficient cholinesterases prolong the duration of the block and contraindicate SCh use in elective anesthesia but are not ordinarily an issue in emergency airway management. Certain conditions, described in the “Adverse Effects” section, place patients at risk for SCh-related hyperkalemia and represent absolute contraindications to SCh. These patients should be intubated using

rocuronium. Relative contraindications to the use of SCh are dependent on the skill and proficiency of the intubator and the individual patient's clinical circumstance. The role of difficult airway assessment in the decision regarding whether a patient should undergo RSI is discussed in Chapters 2 and 3.

Dosage and Clinical Use

In the normal size adult patient, the recommended dose of SCh for emergency RSI is 1.5 mg/kg IV. When patients present with compromised circulation or shock, we recommend increasing the dose to 2.0 mg/kg IV to compensate for reduced IV drug delivery. In a rare, life-threatening circumstance when SCh must be given intramuscularly (IM) because of inability to secure venous access, a dose of 4 mg/kg IM may be used. Absorption and delivery of drug will be dependent on the patient's circulatory status. IM administration may result in a prolonged period of vulnerability for the patient, during which respirations will be compromised, but relaxation is not sufficient to permit intubation. Bag-mask ventilation will usually be required before laryngoscopy in this circumstance.

SCh is dosed on a total body weight basis. In the emergency department, it may be impossible to know the exact weight of a patient, and weight estimates, especially of supine patients, have been shown to be notoriously inaccurate. In those uncertain circumstances, it is better to err on the side of a higher dose of SCh to ensure adequate patient paralysis. The serum half-life of SCh is < 1 minute, so doubling the dose increases the duration of block by only 60 seconds. SCh is safe up to a cumulative dose of 6 mg/kg. At doses >6 mg/kg, the typical phase 1 depolarization block of SCh becomes a phase 2 block, which changes the pharmacokinetic displacement of SCh from the motor endplate. Although the electrophysiologic features of a phase 2 block resemble that of a nondepolarizing or competitive block (train-of-four fade and posttetanic potentiation), the block remains nonreversible. This prolongs the duration of paralysis but is otherwise clinically irrelevant. The risk of an inadequately paralyzed patient who is difficult to intubate because of an

inadequate dose of SCh greatly outweighs the minimal potential for adverse effects from excessive dosing.

In children younger than 10 years, length-based dosing is recommended, but if weight is used as the determinant, the recommended dose of SCh for emergency RSI is 2 mg/kg IV, and in the infant (younger than 12 months), the appropriate dose is 3 mg/kg IV. Some practitioners routinely administer atropine (0.02 mg/kg IV) to children younger than 12 months who are receiving SCh, but there is no high-quality evidence to support this practice. There is, on the other hand, no evidence that it is harmful. When adults or children of any age receive a second dose of SCh, bradycardia may occur, and atropine should be readily available.

Adverse Effects

The recognized side effects of SCh include fasciculations, hyperkalemia, bradycardia, prolonged neuromuscular blockade, MH, and trismus/masseter muscle spasm. Each is discussed separately.

Fasciculations

Fasciculations are believed to be produced by stimulation of the nicotinic ACH receptors. Fasciculations occur simultaneously with increases in intracranial pressure (ICP), intraocular pressure, and intragastric pressure, but these are not the result of concerted muscle activity. Of these, only the increase in ICP is potentially clinically important.

The exact mechanisms by which these effects occur are not well elucidated. In the past, it was recommended that nondepolarizing agents be given in advance of SCh to mitigate ICP elevation, but there is insufficient evidence to support this practice, and they are no longer recommended.

The relationship between muscle fasciculation and subsequent postoperative muscle pain is controversial. Studies have been variable with respect to prevention of fasciculations and subsequent muscle pain. Although there exists a theoretical concern regarding the extrusion of vitreous in patients with open globe injuries who are given SCh, there are no published reports of this potential complication. Anesthesiologists continue to use SCh as a muscle relaxant in cases of open globe injury, with or without an accompanying defasciculating agent. Similarly, the increase

in intragastric pressure that has been measured has never been shown to be of any clinical significance, perhaps because it is offset by a corresponding increase in the lower esophageal sphincter pressure.

Hyperkalemia

Under normal circumstances, serum potassium increases minimally (0-0.5 mEq/L) when SCh is administered. In certain pathologic conditions, however, a rapid and dramatic increase in serum potassium can occur in response to SCh. These pathologic hyperkalemic responses occur by two distinct mechanisms: receptor upregulation and rhabdomyolysis. In either situation, potassium increase may approach 5 to 10 mEq/L within a few minutes and result in hyperkalemic dysrhythmias or cardiac arrest.

Two forms of postjunctional receptors exist: mature (junctional) and immature (extrajunctional). Each receptor is composed of five proteins arranged in a circular fashion around a common channel. Both types of receptors contain two β-subunits. ACH must attach to both β-subunits to open the channel and effect depolarization and muscle contraction. When receptor upregulation occurs, the mature receptors at and around the motor endplate are gradually converted over a 3- to 5-day period into immature receptors that propagate throughout the entire muscle membrane. Immature receptors are characterized by low conductance and prolonged channel opening times (4 times longer than mature receptors), resulting in increasing release of potassium. Most of the entities associated with hyperkalemia during emergency use of SCh are the result of receptor upregulation. Interestingly, these same extrajunctional nicotinic receptors are relatively refractory to nondepolarizing agents, so larger doses of rocuronium may be required to produce paralysis. This is not an issue in emergency RSI, where full intubating doses several times greater than the ED95 for paralysis are used.

Hyperkalemia may also occur with rhabdomyolysis, most often that associated with myopathies, especially inherited forms of muscular dystrophy. When severe hyperkalemia occurs related to rhabdomyolysis, the mortality approaches 30%, almost 3 times higher than that in cases of receptor upregulation. This mortality increase may be related to coexisting cardiomyopathy. SCh is a toxin to unstable membranes in any patient with a myopathy and should be avoided.

Patients with the following conditions are at risk for SCh-induced hyperkalemia:

- Receptor Upregulation
  - **Burns**—In burn victims, the extrajunctional receptor sensitization becomes clinically significant 3 days postburn. It lasts an indefinite period of time, at least until there is complete healing of the burned area. If the burn becomes infected or healing is delayed, the patient remains at risk for hyperkalemia. It is prudent to avoid SCh in burned patients beyond this window if any question exists regarding the status of their burn. The percentage of body surface area burned does not correlate well with the magnitude of hyperkalemia. Significant hyperkalemia has been reported in patients with as little as 8% total body surface area burn (less than the surface of one arm), but this is rare. Most emergent intubations for burn patients are performed well before the 3-day window period. Should a later intubation become necessary, however, rocuronium should be used.
  - **Denervation**—The patient who suffers a denervation event, such as spinal cord injury or stroke, is at risk for hyperkalemia from approximately the third day postevent, until 6 months postevent. Patients with progressive neuromuscular disorders, such as multiple sclerosis or amyotrophic lateral sclerosis, are perpetually at risk for hyperkalemia. Likewise, patients with transient neuromuscular disorders, such as Guillain-Barre syndrome or wound botulism, can develop hyperkalemia after day 3, depending on the severity of their disease. As long as the neuromuscular disease is dynamic, there will be augmentation of the extrajunctional receptors, which increases the risk for hyperkalemia. These specific clinical situations should be considered absolute contraindications to SCh during the designated time periods.
  - **Crush injuries**—The data regarding crush injuries are scant. The hyperkalemic response begins about 3 days postinjury, similarly to denervation, and persists for several months after healing seems complete. The mechanism appears to be receptor upregulation.
  - **Severe infections**—This entity seems to relate to established, serious infections, usually in the ICU environment, and relative

patient immobility that accompanies these conditions. The mechanism is receptor upregulation, but the initiating event is not established. Total body muscular disuse atrophy and chemical denervation of the ACH receptors, particularly related to long-term infusions of NMBAs, appear to drive the pathologic receptor changes. Again, the at-risk time period begins as early as 3 days after initiation of the infection and continues indefinitely as long as the disease process is dynamic. Any serious, prolonged, debilitating infection should prompt concern.

- **Myopathy.** SCh is absolutely contraindicated in patients with inherited myopathies, such as muscular dystrophy. Myopathic hyperkalemia can be devastating because of the combined effects of receptor upregulation and rhabdomyolysis. This is a particularly difficult problem in pediatrics, when a child with occult muscular dystrophy receives SCh. SCh has a black box warning advising against its use in elective pediatric anesthesia, but it continues to be a strong muscle relaxant option for emergency intubation. Any patient suspected of a myopathy should be intubated with nondepolarizing muscle relaxants rather than SCh.
- **Preexisting Hyperkalemia.** Hyperkalemia, per se, is not an absolute contraindication to SCh. There is little evidence that the normal SCh-induced potassium rise of 0.5 mEq/L is harmful in patients with preexisting hyperkalemia who are not otherwise at risk for severe SCh-induced hyperkalemia by one of the mechanisms described in the preceding section. In fact, there is only one published report that documents this phenomenon. Despite this lack of significant evidence, there is widespread concern that patients with hyperkalemia secondary to acute kidney injury or acidotic conditions like diabetic ketoacidosis are likely to exhibit cardiac dysrhythmias from SCh administration. The largest study that examined the use of SCh in patients with chronic renal failure (including documented hyperkalemia before intubation) failed to identify any adverse effects related to SCh. Therefore, a reasonable approach is to assume that SCh is safe to use in patients with preexisting hyperkalemia or renal failure unless the ECG (either monitor tracing or 12-lead ECG) shows evidence of myocardial

instability from hyperkalemia (prolongation of the QRS complex or sine wave morphology).

Bradycardia

In both adults and children, repeated doses of SCh may produce bradycardia, and administration of atropine may become necessary.

Prolonged Neuromuscular Blockade

Prolonged neuromuscular blockade may result from an acquired PCHE deficiency, a congenital absence of PCHE, or the presence of an atypical form of PCHE, any of the three of which will delay the degradation of SCh and prolong paralysis. Acquired PCHE deficiency may be a result of liver disease, chronic cocaine abuse, pregnancy, burns, oral contraceptives, metoclopramide, bambuterol, or esmolol. A 20% reduction in normal levels will increase apnea time by about 3 to 9 minutes. The most severe variant (0.04% of population) will result in prolonged paralysis for 4 to 8 hours.

Malignant Hyperthermia

A personal or family history of MH is an absolute contraindication to the use of SCh. MH is a myopathy characterized by a genetic skeletal muscle membrane abnormality of the Ry (ryanodine) receptor. It can be triggered by halogenated anesthetics, SCh, vigorous exercise, or emotional stress. Following the initiating event, its onset can be acute and progressive or delayed for hours. Generalized awareness of MH, earlier diagnosis, and the availability of dantrolene (Dantrium) have decreased the mortality from 70% to 5%. Acute loss of intracellular calcium control results in a cascade of rapidly progressive events manifested primarily by increased metabolism, muscular rigidity, autonomic instability, hypoxia, hypotension, severe lactic acidosis, hyperkalemia, myoglobinemia, and disseminated intravascular coagulation. Temperature elevation is a late manifestation. The presence of more than one of these clinical signs is suggestive of MH.

Masseter spasm, once claimed to be the hallmark of MH, is not pathognomonic. SCh can promote isolated masseter spasm as an exaggerated response at the neuromuscular junction, especially in children.

The treatment for MH consists of discontinuing the known or suspected precipitant and the immediate administration of dantrolene sodium

(Dantrium). Dantrolene is essential to successful resuscitation and must be given as soon as the diagnosis is seriously entertained. Dantrolene is a hydantoin derivative that acts directly on skeletal muscle to prevent calcium release from the sarcoplasmic reticulum without affecting calcium reuptake. The initial dose is 2.5 mg/kg IV, repeated every 5 minutes until muscle relaxation occurs or the maximum dose of 10 mg/kg is administered. Dantrolene is free of any serious side effects. In addition, measures to control body temperature, acid-base balance, and renal function must be used. All cases of MH require frequent monitoring of pH, arterial blood gases, and serum potassium. Immediate and aggressive management of hyperkalemia with the administration of calcium gluconate, glucose, insulin, and sodium bicarbonate may be necessary. Interestingly, full paralysis with nondepolarizing NMBAs will prevent SCh-triggered MH. MH has never been reported to be related to the use of SCh in the emergency department. The MH emergency hotline number is 1-800-MH-HYPER 1-800-644-9737 (United States and Canada) 24 hours a day, 7 days a week. Ask for “index zero.” The e-mail address of the Malignant Hyperthermia Association of the United States (MHAUS) is mhaus@norwich.net, and the website is www.mhaus.org.

Trismus/Masseter Muscle Spasm

On occasion, SCh may cause transient trismus/masseter muscle spasm, especially in children. This manifests as jaw muscle rigidity associated with limb muscle flaccidity. Pretreatment with defasciculating doses of nondepolarizing NMBAs will not prevent masseter spasm. If masseter spasm interferes with intubation, an intubating dose of a competitive nondepolarizing agent (eg, rocuronium 1 mg/kg) should be administered and will relax the involved muscles. The patient may require bag-mask ventilation until relaxation is complete and intubation is possible. Masseter spasm should prompt serious consideration of the diagnosis of MH (see previous discussion).

COMPETITIVE NEUROMUSCULAR BLOCKING AGENT

Nondepolarizing (Competitive) NMBAs				
	Intubating Dose	Time to Intubation-Level	Duration	Pregnancy

	(mg/kg)	Paralysis (sec)	(min)	Category
Rocuronium	1.5	60	40-60	B

Clinical Pharmacology

The nondepolarizing, or competitive, NMBAs compete with and block the action of ACH at the motor endplate's postjunctional, cholinergic nicotinic receptors. The blockade is accomplished by competitively binding to one or both of the β-subunits in the receptor, preventing ACH access to both α-subunits, which is required for muscle depolarization. This competitive blockade is characterized by the absence of fasciculations. It can be reversed by ACHE inhibitors that normally prevent the metabolism of ACH. ACHE inhibitors cause ACH reaccumulation at the motor endplate, which competes with the competitive NMBA and promotes muscular contraction.

For the most part, nondepolarizing NMBAs are eliminated by Hofmann degradation (atracurium and cisatracurium) or excreted unchanged in bile (rocuronium), although there is limited liver metabolism and renal excretion of both vecuronium and rocuronium. They are divided into two groups: the benzylisoquinoline compounds (eg, D-tubocurarine, atracurium, and mivacurium) and the aminosteroid compounds (eg, rocuronium). The only agent commonly used for emergency RSI is rocuronium.

Rocuronium does not significantly release histamine or cause ganglionic blockade. Rocuronium has a slight vagolytic effect. It is lipophilic, eliminated primarily in bile, and very stable from a cardiovascular standpoint. Rocuronium is the principal competitive NMBA for emergency RSI because its onset time and duration of action are the shortest of all nondepolarizing NMBAs.

Rocuronium can be reversed by administering ACHE inhibitors such as neostigmine (Prostigmin) 0.06 to 0.08 mg/kg IV after significant (40%) spontaneous recovery has occurred. Atropine 0.01 mg/kg IV or glycopyrrolate (Robinul) 0.01 to 0.05 mg/kg/IV can be given routinely to block excessive muscarinic stimulation (SLUDGE syndrome—Salivation, Lacrimation, Urination, Diarrhea, Gastrointestinal Upset, Emesis). Reversal of blockade is virtually never indicated following emergency airway management.

A new selective rocuronium reversal agent, sugammadex, is now approved for use in the United States. Its hollow, cone-shaped polysaccharide molecular structure encapsulates rocuronium and, to a lesser extent, vecuronium, thereby reversing the neuromuscular block without the muscarinic side effects of the ACHE inhibitors. Spontaneous breathing is restored in ~ 3 minutes, compared to more than 5 minutes with the ACHE inhibitors. In addition, sugammadex is rapidly effective at a dose of 16 mg/kg IV, regardless of the extent of the neuromuscular block, and it is not necessary for any spontaneous recovery to occur before reversal is initiated. See “Evidence” section for details.

Unfortunately, sugammadex has not shown to be as useful in emergency RSI as previously hoped. It takes minutes to mix the drug, and doses are expensive. Although it can be used in a planned scenario, such as to reestablish neuromuscular function to evaluate extent of brain injury or continuation of status epilepticus postintubation, its use in a can’t-intubate and can’t-oxygenate (CI:CO) scenario is limited. Premixed syringes available for use are cost-prohibitive. If a CI:CO situation occurs, the many minutes it takes to determine true CI:CO status plus the time to get the drug, mix it, administer it, and await return of spontaneous breathing exceed the life span of an anoxic brain. Additionally, sugammadex does not impact the deep sedation and respiratory depression created by the sedative-induction agent. Furthermore, even if reversal of neuromuscular blockade and spontaneous breathing occurred in time, the original status of the patient requiring them to be intubated would still exist. Therefore, most airway experts agree that the only solution to a true CI:CO scenario is a rapid surgical airway.

Indications and Contraindications

The nondepolarizing NMBAs serve a multipurpose role in emergency airway management. Based on recent registry data, rocuronium is the only nondepolarizing NMBA used for emergency RSI. Any of the nondepolarizing agents (vecuronium, pancuronium, or rocuronium) are appropriate for maintenance of paralysis after intubation, when this is desired. The only contraindication to a nondepolarizing NMBA is known prior anaphylaxis to that agent, although this is exceedingly rare. Patients

with myasthenia gravis are sensitive to NMBAs and may experience greater, or more prolonged, paralysis at any given dose.

Dosage and Clinical Use

The recommended dose of rocuronium for emergency airway management is 1.5 mg/kg IV. It produces intubation-level paralysis consistently within 60 seconds, especially when an adequate dose of induction (sedative) agent is used, because the induction agent also causes substantial relaxation. For postintubation management when continued neuromuscular blockade is desired, vecuronium 0.1 mg/kg IV or pancuronium 0.1 mg/kg IV is appropriate, in concert with adequate sedation (see Chapters 20 and 30). **Table 22.1** lists the onset and duration of action for routine paralyzing doses of all commonly used NMBAs. The onset times and durations are for the specific doses listed, which are lower than the doses used for intubation.

TABLE 22.1 Onset and Duration of Action of Neuromuscular Blocking Drugs

Drug	Dose (mg/kg)	Time to Maximal Blockade (min)	Time to Recovery (min)	
			25%	75%
Quaternary amine				
SCh	1.5	1.1	8	11 (90%)
Aminosteroid compounds				
Rocuronium	1.5	1.0	43	66

From Hunter JM. Drug therapy: new neuromuscular blocking drugs. *N Engl J Med.* 1995;332:1691-1699. Copyright © 1995 Massachusetts Medical Society. Reprinted with permission from Massachusetts Medical Society.

Adverse Effects

Previously, the nondepolarizing NMBAs were considered less desirable for intubation than SCh because of delayed time to paralysis, prolonged duration of action, or both. However, their onset can be shortened by administering a larger intubating dose (as opposed to the ED95 dose [Table 22.1] used for surgical paralysis), and the availability of sugammadex allows premature termination of neuromuscular blockade should that be needed.

EVIDENCE

What is the advantage to RSI with an NMBA versus intubation with deep sedation alone?

RSI with an NMBA is the current standard of care for emergency intubation. Multiple prospective studies and ED registry data confirm the high success rate of RSI with NMBAs when performed by experienced operators in both adult and pediatric emergency patients.[1–3]

Are any of the nondepolarizing NMBAs as good as SCh for emergency RSI?

Multiple studies have compared SCh with rocuronium for intubation. All have concluded that the intubating conditions of the two drugs are very similar, provided they are dosed correctly. Recent reviews comparing SCh and rocuronium for emergency department RSI by emergency physicians demonstrate no significant difference between intubation success with either agent.[4–11] The dose of rocuronium is critical to the success of RSI. The correct dose of rocuronium previously advocated for RSI was 1.0 to 1.2 mg/kg, not 0.6 mg/kg, as is commonly used in the operating room. A 2015 Cochrane review concluded that SCh at 1.5 mg/kg IV compared to rocuronium at 1.0 mg/kg IV produced superior intubating conditions more often, but equivalent rates of acceptable intubating conditions. However, rocuronium at 1.2 mg/kg IV gives equivalent intubating conditions as SCh, but the duration of action is longer than 1.0 mg/kg IV, and far longer than that of SCh.[7] The duration of the 1.0 mg/kg IV dose is 46 minutes.

What is the correct dose of SCh for RSI?

Intubating conditions are directly related to the dose of SCh used, with excellent intubating conditions in more than 80% of patients receiving 1.5 mg/kg IV or more of SCh.[12] Increasing the dose of SCh from 1.5 to 2 mg/kg IV increases the duration of action only from 5.2 to 7.5 minutes, reinforcing the notion that the half-life of SCh in vivo is about 1 minute. There is sufficient evidence that decreasing doses of SCh produce inferior intubating conditions. Therefore, we firmly recommend 1.5 mg/kg IV (or more) of SCh for emergent RSI.

What is the correct dose of rocuronium for RSI?

The new recommendation for RSI is 1.5 mg/kg IV. Over the past several years, the weight-based recommendation for rocuronium has been escalating in concert with evidence showing that intubating conditions are maximized with higher doses. A recent analysis from the National Emergency Airway Registry (NEAR) of stratified weight-based doses of rocuronium revealed that first-attempt intubation success was highest when more than 1.4 mg/kg IV of rocuronium was used (92% vs 88% for 1.0 mg/kg IV).[13] The benefit was most pronounced in patients with hypotension and for whom direct laryngoscopy was performed. In the latter group, the adjusted odds of a first-attempt success was 1.9 (95% CI 1.3-2.7) when 1.4 mg/kg or more of rocuronium was used. This benefit was not observed in the videolaryngoscopy (VL) group, likely because glottic visualization was enhanced sufficiently by the video technology so that additional neuromuscular blockade did not confer a benefit; however, there is little downside to using higher dosing even when VL is planned. In emergency patients, weight is often estimated and, if guessed low—which is often the case—inadequate total NMBA could result in partial paralysis and poor intubating conditions. At 1.0 mg/kg IV, a patient will be relaxed for ~ 45 minutes. Successful airway management is required long before this to avoid anoxic injury. Therefore, although administering a higher weight-based dose of rocuronium will extend the clinical duration of action, it does not introduce greater patient risk. Given this, and in an effort to simplify NMBA dosing, 1.5 mg/kg IV is now the recommended RSI dose for both SCh and rocuronium.

SCh use in patients with open eye injuries

SCh has been linked to an increase in intraocular pressure. However, there has never been a case report of vitreous extrusion following the use of SCh in a patient with an open globe injury. Therefore, we recommend that the NMBA for RSI in patients with open globe injury be selected as for any other patient.

SCh use in denervation injuries (stroke, Guillain-Barré syndrome, polio, spinal cord trauma, etc.)

Denervation injuries cause a change in the number and function of junctional and extrajunctional ACH receptors as early as 3 days

postinjury.[14,15] This can result in massive serum potassium increases that can cause cardiac arrest. SCh can be safely used up to 3 days postdenervation and should then be avoided until muscle atrophy is complete and the event is no longer dynamic.

SCh use in myopathic patients (muscular dystrophy, rhabdomyolysis, crush injuries, prolonged immobility, etc.)

Myopathies cause hyperkalemia through a mechanism similar to denervation, that is, changes in ACH receptor function and density.[16] Congenital myopathies are considered as an absolute contraindication to SCh; its use in patients with myopathies can result in rhabdomyolysis and resuscitation-resistant hyperkalemic arrest.[17,18] Hyperkalemia secondary to occult, undiagnosed myopathy must be considered in children who experience cardiac arrest after SCh.[19] When a patient with known rhabdomyolysis is encountered, SCh should be avoided.

SCh use in patients with preexisting hyperkalemia

Few studies to date have examined the risk of SCh administration in hyperkalemic patients.[20] In a meta-analysis, Thapa and Brull identified four controlled studies of patients with and without renal failure, and there were no cases in which serum potassium increased by more than 0.5 mEq/L.[21] The largest series, involving more than 40 000 patients undergoing general anesthesia, identified 38 adults and children with hyperkalemia (5.6-7.6 mEq/L) at the time they received SCh. None of these patients had an adverse event, and the authors calculated that the maximum likelihood of an adverse event related to SCh in hyperkalemic patients is 7.9%.[20] The long-held dogma to avoid SCh in any patient with renal failure is not valid, and SCh's independence of renal excretion makes it a viable agent to consider when renal function is impaired.[22,23] We recommend that when hyperkalemia is present, or believed to be present (eg, patient with end-stage renal disease) and the ECG shows stigmata of cardiac instability from hyperkalemia (increased QRS duration), an alternative agent, such as rocuronium, should be used for RSI. Otherwise, renal failure, or nominal hyperkalemia (ie, without ECG changes), is not a contraindication to SCh.

Sugammadex evidence

The molecular shape of sugammadex allows it to encapsulate rocuronium and reverse neuromuscular blockade.[24] Early studies demonstrate safe and effective reversal of rocuronium neuromuscular blockade in as little as 2 minutes.[8,24–27] However, its use as a rescue agent in a can't-intubate-can't-oxygenate scenario is not realistic owing to the time required to decide to use it, mix it, administer it, and wait for it to reverse neuromuscular blockade.

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CHAPTER 23

Optimizing First Attempt Intubation Success

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IMPORTANCE OF FIRST ATTEMPT INTUBATION SUCCESS

Achieving first attempt intubation success is crucial for patients undergoing emergency intubation. Failure to intubate successfully on the first attempt is associated with increased risk of hypoxemia, aspiration, cardiac arrest, and other peri-intubation complications. Although first attempt success has improved with better training and the introduction of video laryngoscopy, estimated first attempt success rates in the emergency department (ED) remain near 90%, with lower rates in the intensive care unit. Approximately 1.5 million critically ill adult patients are intubated annually in the United States—90% first attempt success translates to at least 150 000 patients requiring multiple attempts before successful intubation. Because there is an adverse event rate of 30% to 50% when the first attempt fails, there is clear room for improvement in this measure. Proper patient assessments, preparation, use of checklists, and consistent video assistance have allowed some EDs and prehospital groups to achieve first attempt success rates >95%. This suggests that rather than depending mostly on individual skill, intubation success hinges heavily on intubation systems that support the clinician.

KEYS TO OPTIMIZING FIRST ATTEMPT INTUBATION SUCCESS AND SAFETY

Optimizing first attempt intubation success requires consistently using the best practices for *all facets* of intubation. Success does not occur by chance or by recruiting residents, fellows, or staff with unusually good hand-eye coordination. It occurs by paying meticulous attention to the entire process of intubation. Elements with the greatest effect on first attempt intubation success and patient safety include:

1. A standardized approach to all intubations
2. Appropriate use of rapid sequence intubation
3. Following a checklist to meticulously prepare for intubation
4. Robust preoxygenation
5. Using the best device, technique, and adjuncts
6. Algorithmic decision-making
7. Early use of well-practiced rescue tools
8. Taking ownership with continuous quality improvement by an airway lead

USE A STANDARDIZED APPROACH TO EMERGENCY INTUBATION

This may be the most important element affecting first attempt intubation success and the safety of emergency intubation. Emergency intubation is a complex process, and there is still debate about which equipment and techniques are best—however, each department should decide on and standardize best practices for their group. Emergency intubation is often a stressful event and involves multiple team members—a consistent approach leads to better teamwork, decreased stress, and fewer mistakes.

Departments should adopt an approach to intubation that standardizes intubation preparation, medications, techniques, and devices for nearly all patients who require intubation. The standard approach should use the best available techniques and equipment—this will ensure that the standard approach will be successful for difficult cases. Using new, unfamiliar, or rarely used techniques or devices for difficult airways will often translate to unanticipated challenges or intubation failure.

Randomized trials in the ICU and ED have studied singular elements of the intubation process, including using a checklist versus no checklist; using a direct versus video laryngoscope; placing the patient in a sniffing versus ramped position; and use of apneic oxygenation versus no apneic oxygenation, with results showing individual aspects of airway management may not have as much impact on intubation success as system-wide changes. These trials all have limitations (eg, studying only novice operators) and, rather than demonstrating the futility of checklists, video laryngoscopes, intubation position, and the use of apneic oxygenation, they suggest that altering just one element in a complex process may not alter outcomes.

Emergency tracheal intubation is complex, and all elements of the procedure, before, during, and after tube placement, contribute to patient safety. For instance, using a checklist will not help if the patient is not positioned properly; positioning the patient will not help if a direct laryngoscope is used for a difficult airway; and using a video laryngoscope might not help if preoxygenation is inadequate, leading to truncated laryngoscopy time. Departments and intubators must pay particular attention to *all* elements of intubation, sometimes termed the *process* of intubation or the airway bundle. When an intubator—or entire department—uses a standard airway bundle that uses the best of all available techniques and equipment, this greatly simplifies the complexity of the procedure and delivers the best care to the patient.

THE IMPORTANCE OF NEUROMUSCULAR BLOCKADE FOR EMERGENCY INTUBATION

Perhaps nothing aids more in first attempt intubation success than neuromuscular blockade. Before the introduction of rapid sequence intubation (RSI—see Chapter 20), intubation was significantly more difficult, and first attempt success was uncommon.

Because of the powerful human instinct to protect the airway, placement of the laryngoscope and tube without paralysis often results in a physical struggle, poor intubating conditions, and trauma to the airway. RSI is the most commonly used method for emergency intubation. Multiple prospective studies and ED registry data confirm the high success rate of

RSI with neuromuscular blocking agents when performed by experienced operators in both adult and pediatric emergency patients (see “Evidence” section of Chapter 20). Paradoxically, the belief that using sedatives alone without neuromuscular blockade was safer often caused more harm. Significant sedation is required to facilitate laryngoscopy and oral intubation, which commonly results in hypoventilation or apnea. Instrumenting the airway in this state can also cause vomiting, which can be disastrous in a patient without intact airway reflexes.

Appropriate Use of Rapid Sequence Intubation

RSI has revolutionized emergency airway management and is associated with improved intubation success and safety. In intubation registries, a neuromuscular blocking agent is used in ~ 85% of all airway encounters and in >95% of patients when those with cardiac arrest are excluded. This very high rate demonstrates that RSI should be the default method to facilitate intubation unless there is a compelling reason to select a method that will maintain spontaneous breathing (ie, significant anatomic or physiologic difficulty—see Chapters 2 and 3)—not the other way around.

When intubators are confident in the airway plan and backup devices, and are using the best equipment, they will have confidence in the success of the procedure and the success of rescue oxygenation, which will allow use of RSI.

Use Awake Intubation When Both RSI and Rescue Oxygenation Are Likely to Fail

RSI should be avoided when intubation, rescue oxygenation, or both are deemed very difficult or potentially impossible. Less than 5% of patients will meet these criteria. The algorithms in Chapters 2 and 3 provide an excellent framework for assessing the difficult airway. Chapter 5 outlines the algorithmic application of this knowledge to help construct the appropriate plan. The intubator must understand the importance of the decision branch point between RSI and awake intubation and not overutilize awake techniques. However, intubators should not be cavalier in their approach to patients with difficult airway characteristics. When modern equipment and techniques are used, it is rare that a patient cannot

be intubated or reoxygenated; however, these cases still exist, and therefore awake intubation remains a valuable tool.

The decision to use an awake technique cannot rely solely on mnemonics and individual difficult airway markers (because at least one marker is present in 60% of emergency intubations) and must instead rely on the judgment of the intubator when considering patient characteristics, available equipment, and their level of skill and experience. Additionally, there are times when awake intubation is being considered but may not be the most practical approach, including rapidly progressing upper airway obstruction with no time for patient preparation (see Chapter 24) or a trauma patient with penetrating neck wound and copious oropharyngeal bleeding. These patients often fit in the "forced to act" category in the difficult airway algorithm (see Chapter 5).

If RSI is avoided, the patient should ideally be kept fully or nearly fully awake, and intubation should be performed after meticulous application of topical anesthesia (Chapters 17 and 24). If awake intubation is not possible because of lack of patient cooperation, even after liberal topical anesthesia, small amounts of sedative agents, given serially, can be administered. The goal is not to make the patient obtunded or unconscious but to achieve the minimum level of sedation that facilitates patient tolerance and cooperation with the procedure. When significant sedation is given without neuromuscular blockade, respirations and protective airway reflexes are compromised, but laryngoscopy remains challenging owing to the patient's intrinsic resistance to laryngoscope insertion and laryngeal manipulation. This can lead to airway trauma, poor glottic views, and vomiting with aspiration. All efforts should be made to make the procedure tolerable yet preserve breathing and airway reflexes until the tube is in the trachea. RSI medications and backup equipment should be readied when performing an awake intubation.

Avoid Sedation-Only Intubations

In contrast to a true awake intubation, a sedation-only intubation, defined as intubation after administration of a higher dose sedative that renders the patient obtunded, should be avoided. This is still advocated for in some hospitals and ICUs for fear of using neuromuscular blockade. It is

erroneously believed that sedation-only intubation is a safer alternative for patients with predicted difficulty because it avoids paralysis in patients with markers of airway difficulty. However, this approach leads to compromised respirations and airway reflexes, worse intubating conditions, and lower first attempt success and places the patient at risk for vomiting and aspiration. Occasionally, this approach is promoted to assess the feasibility of intubation by attempting to view the glottis after the patient is more deeply sedated. It is thought that if glottic structures are visualized, then one is reassured of success and can proceed with RSI.

Performing laryngoscopy with significant sedation but without neuromuscular blockade with the intention to assess intubation difficulty leads to two possibilities: (i) the intubation appears likely to be successful, and a neuromuscular blocking agent is then administered and intubation performed, or (ii) the intubation appears unlikely to be successful, and the intubator is not certain whether this is because of patient anatomy or inadequate patient relaxation—in these cases, a neuromuscular blocking agent is commonly administered to improve intubating conditions (or the intubator performs a cricothyrotomy or administers a neuromuscular blocking agent and places an extraglottic device). The outcomes for the latter scenario highlights the challenge of the misnamed “awake look” technique. This argues, instead, for the intubator to choose either RSI or a fully (or near-fully) awake airway intubation or airway evaluation.

IMPORTANCE OF A PREINTUBATION CHECKLIST

Emergency intubation is analogous to other high-risk situations such as flying an airplane or skydiving, where small mistakes can result in catastrophe. Hence, checklists are commonly used in these and other high-risk activities. Multiple studies have shown that implementing a checklist as part of an airway bundle improves first attempt intubation success.

Seemingly small details can make the difference between a straightforward intubation and an airway disaster. Details that may be missed without a checklist include ensuring the intravenous line is patent, that suction is turned on, and that the video laryngoscope screen is functional. Using a checklist encourages a team approach to airway management and ensures that all members of the team are aware of the

plan. Checklists affirm that basic skills, techniques, and equipment are key to safe and effective airway management. A sample checklist is provided in **Figure 23.1**. The exact contents of an intubation checklist will vary by institution and are perhaps less important than a rigorous implementation of the checklist to ensure its ongoing use.

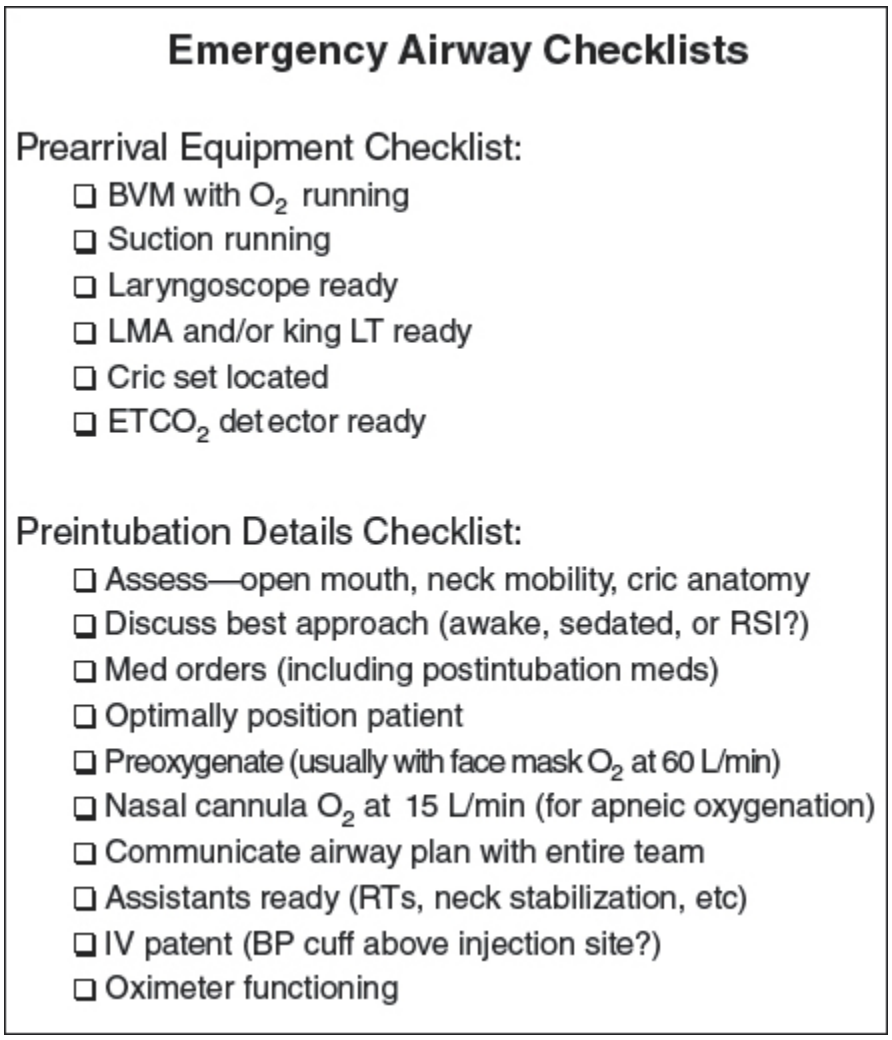

Figure 23.1: An example of a pre-intubation checklist. Checklists, which vary by institution, will remind intubators of best practices that should be standardized for all intubation attempts. (Courtesy of the Department of Emergency Medicine, Hennepin County Medical Center.)

Because 60% of patients undergoing emergency intubation have one or more difficult airway characteristics, all emergency intubations should be considered potentially difficult and deserving of meticulous preparation. A checklist will ensure that you are always prepared when difficulty arises.

Many elements of a preintubation checklist are covered in other chapters. Here, we provide a brief summary of key elements to stress their importance to the process of intubation.

Assess the Airway

Time and clinical circumstances permitting, the intubator should assess the predicted difficulty of bag-mask ventilation, extraglottic device placement, and laryngoscopy (Chapter 2). At a minimum, the intubator should assess mouth opening and neck mobility and consider whether there could be any obstruction between the mouth and the airway. This will guide formation of the airway plan.

Position the Patient Perfectly

Positioning, covered in more detail in Chapters 15 and 16, can determine first attempt success or failure as much as whether RSI, preoxygenation, and video laryngoscopy are used. Aligning the ear to the sternal notch by elevating the head relative to the chest while keeping the face parallel to the ceiling is beneficial with all intubations, provided cervical spine injury is not suspected (**Fig. 23.2**). The straightest path between the mouth and the larynx helps with both laryngoscopy and tube delivery, no matter which laryngoscope is used. Each patient will require slightly different maneuvers to achieve the perfect position: some will need nothing; some will need a towel placed behind the neck or shoulders; others, particularly obese patients, will require ramping of the bed or with commercially available devices. This can be refined during laryngoscopy but should be set up as close to the ideal position as possible before intubation.

Figure 23.2: The ideal patient position aligns the anterior ear with the sternal notch. This is most often accomplished by elevating the head of the patient while keeping the face parallel to the ceiling. (Courtesy of the Department of Emergency Medicine, Hennepin County Medical Center.)

Prepare Excellent Suction

Apart from the blade, bougie, and tube, suction is the only other device that enters the patient's mouth. For some patients, adequate suction determines not only the success or failure but whether there is large volume aspiration of blood, secretions, or gastric contents into the trachea. Standard tonsil (commonly known as Yankauer) and dental suction tips as well as standard suction tubing (internal diameter 5 mm) have narrow diameters and are easily clogged by blood or vomit. The best suctioning equipment for patients with significant bleeding or vomit in the airway includes a large-bore tip with a tip internal diameter of at least 1/4-in (eg, Big Stick and DuCanto catheter from SSCOR, Inc.; Sun Valley, CA) and 5/16-in (~ 8 mm) internal diameter suction tubing (eg, Kuriyama Tubing, clear PVC).

Select and Locate Rescue Devices

Always expect a difficult airway. Select, locate, and have ready backup devices, including a bag-mask device, extraglottic airway, and cricothyrotomy kit. This mental and physical preparation will improve confidence in the success of the procedure overall, particularly in rescue oxygenation and ventilation.

OPTIMAL PREOXYGENATION IS CRITICAL

Preoxygenation is critical to the success of emergency intubation because it extends the amount of time the patient maintains a normal oxygen saturation while apneic, allowing more time for the intubation procedure (see Chapters 8 and 20). Ideally, patients should be preoxygenated for 3 minutes or 8 maximal capacity breaths if time is short. It is best to preoxygenate patients in a head-elevated position. There are two simple methods that provide adequate preoxygenation.

1. **High flow of oxygen**. The easiest method to provide a high flow of oxygen is to use a non-rebreather (NRB) facemask with the oxygen flow rate set as high as possible (ie, flush-flow rate, usually 40-60 L/min), achieved by rotating the knob of a standard flowmeter until it will not rotate further; the flow of oxygen will be quite loud. This is the default initial preoxygenation method for all emergency intubations. Standard nasal tubing set to 5 to 15 L/min is placed under the NRB mask and left in place during intubation to prolong the period of safe apnea. Humidified high-flow nasal oxygen (HFNO) is also an option but requires special equipment.
2. **Oxygen with positive pressure**. This is best for patients with underlying respiratory pathology or obesity and is most often accomplished with noninvasive positive pressure ventilation, which provides high-quality ventilation closely synchronized with the patient's breathing. Using a bag-valve-mask device with a positive end expiratory pressure valve, without providing ventilation, and with other supplemental oxygen under the mask, is a consideration but caution should be exercised because it requires the patient to have sufficient ventilatory effort to draw volume from the bag's reservoir

and a team member to continuously maintain a *perfect* mask seal. Unless the patient is apneic, manual bag ventilation is not recommended. For spontaneously breathing patients, it is difficult to synchronize the bag-mask device with the patient's breathing, and this method provides only negligible positive pressure.

MAKE THE FIRST ATTEMPT THE BEST ATTEMPT

Use the best equipment, best techniques, and best personnel on the first attempt, rather than withholding some better equipment, technique, or personnel until after the first attempt fails. For most emergency intubations, the primary tool used on first attempt should be a video laryngoscope with both standard geometry and hyperangulated blades.

Set the Scene

When performing tracheal intubation of critically ill patients, distractions should be forbidden unless necessary to prevent morbidity or death. This is analogous to the sterile cockpit rule in aircraft that prohibits nonessential activities during taxiing, takeoff, and landing. Before the intubation procedure, instruct a team member to notify the room when the patient's oxygen saturation reaches a certain threshold (eg, 93%)—this is much preferred to calling out decreasing oxygen saturation levels that are not actionable (eg, "99%, 98%, 96%," and so on).

The remainder of the team (eg, nurses, health care assistants, students) should be briefed on the airway plan and their role for the initial procedure and any backup procedures. Ideally, a department would have a very similar approach to most intubations so that the team can become familiar with a routine, which will increase comfort and proficiency.

Identify one main assistant to aid with the procedure. This assistant will hand you the suction device, bougie, and endotracheal tube and may assist with external laryngeal manipulation. Ensure the assistant can see the video screen so they can better aid in the procedure and more quickly troubleshoot problems that arise. This assistant can also be responsible for ensuring checklist items are completed.

Use the Best Laryngoscope

Select the laryngoscope that will provide the highest chance of first attempt success. Many advocate for the video laryngoscope to be the default intubation device because it results in a better view, is infrequently soiled by body fluids or blood in the mouth, and in observational studies is associated with higher success, even when compared to augmented direct laryngoscopy with a ramped position, external laryngeal manipulation, and bougie use.

Direct laryngoscopy, a necessary skill to develop and maintain for instances when technology fails or clean blades are not available, can be used if the physician believes it offers the best chance of success, although this should be exceptionally rare. Direct laryngoscopy should be accomplished, whenever possible, using a Macintosh-style videolaryngoscope. This allows direct laryngoscopy with instant video backup should the intubation prove difficult. Institutions that train residents should strongly consider use of a Macintosh-style video laryngoscope so that both direct and video laryngoscopy can be accomplished with one device. Available evidence suggests that Macintosh-style video laryngoscopes achieve similar success to hyperangulated video laryngoscopes for many patients, even when used in patients with suspected cervical spine injury.

Although hyperangulated blades are effective and highly successful in skilled hands, intubators who primarily use hyperangulated video laryngoscopes may not maintain proficiency with direct laryngoscopy, and this could be problematic if the video device is not available or there are technical difficulties.

Perform Optimal Laryngoscopy

Grip the blade near where the handle meets the blade, use good posture, and make sure your face is sufficiently far away from the patient. Do not rush laryngoscopy or put your face right up against the patient’s face. If you feel like you need to rush, you probably need better preoxygenation or a different airway plan. Methodically insert the blade into the mouth, and incrementally move it down the tongue, lifting and looking as you go.

Progressively visualize structures of the uvula, tongue, epiglottis, arytenoid cartilages, glottic opening. Chapters 15 and 16 provide further detail.

Use a Bougie or Stylet With Straight-to-Cuff Shape

Laryngoscopy is only part of the intubation procedure—after obtaining the best possible view, the tube must then be delivered into the trachea. High-quality laryngoscopy and patient positioning can often make tube delivery straightforward, especially when a Macintosh blade is used. However, particular attention should be paid to the shape of the tube, which should follow a straight-to-cuff shape, with a distal bend of 25° to 35°. Using a bougie on the first attempt has been shown to increase first attempt success when incorporated into routine practice and can make tube delivery even easier. The narrower diameter of the bougie makes it easier to insert into the larynx without obscuring the intubator's view of the airway. Previous concerns about significantly longer intubation times or airway trauma with the bougie have not been observed in randomized trials. Routine use during the first attempt of devices normally reserved for difficult airways or after failed intubation attempts (eg, video laryngoscopy and bougie) may improve their success when used for actual difficult airways. Chapters 15 and 16 provide more detail on this important component of intubation.

A SIMPLE ALGORITHM IS INVALUABLE WHEN INTUBATION ATTEMPTS FAIL

This intubation plan should include a simple preconceived airway algorithm with proven techniques that, should the first attempt prove unsuccessful, allows the intubator to move to the next step in the algorithm without having to use precious cognitive bandwidth to make de novo decisions. This framework improves confidence in the ability to maintain oxygenation for the patient. Refer to Chapter 5 for a review of the emergency airway algorithms.

BACKUPS NEED TO BE AVAILABLE, WELL PROVEN, AND WELL PRACTICED

When intubation attempts fail, it is imperative that backup equipment is readily available—at arm's reach and not in a difficult airway cart in another room. Because about half of difficult airways are unexpected, backup equipment needs to be available for both routine intubations and those anticipated to be difficult.

Bag-mask ventilation is the primary backup device. Extraglottic devices (EGDs) are also critically important backup tools and can be used instead of or after bag-mask ventilation. Emergency airway clinicians must realize that all EGDs are not equal and choose their backup devices carefully (see Chapter 13). Specifically, second generation EGDs are designed to allow simultaneous passage of an orogastric tube, some are designed to facilitate blind or endoscopic intubation, and some allow ventilation with higher pressures before leaking. Many departments have only a first-generation laryngeal mask airway as their primary backup device, which cannot empty the stomach, facilitate intubation, or tolerate high ventilation pressure. EDs should stock a later generation EGD and ensure all intubators are familiar with its use.

The final step in all emergency airway algorithms is a surgical approach. A simple open surgical technique using readily available equipment (scalpel, bougie, endotracheal tube, and hook) is recommended by most emergency airway experts.

Regular practice with backup techniques—bag-mask ventilation, EGD placement, and surgical airways—is highly recommended and allows clinicians to manage difficult airway scenarios more comfortably. This mental and physical preparation will improve confidence in the success of the procedure overall, particularly in rescue oxygenation and ventilation, which might lead to more confidence with RSI, and, in turn, increase the chance of first attempt success.

CALLING FOR HELP

Those responsible for emergency intubation should, ideally, be committed to the *entire process* of intubation, including both easy and difficult airways, awake intubation, RSI, rescue with EGDs, and performance of surgical airways. However, humility is key to safe and successful airway

management, especially in difficult cases. Recognizing that an airway will likely be difficult and calling for proper help is important.

Experienced and skilled airway practitioners may just need a few assistants, whereas those with less skill or experience should call the most experienced airway manager available, ideally another emergency physician or someone who manages emergency airways regularly.

Although it may be common for some emergency clinicians to call on anesthesiologists for awake intubation or surgeons for surgical airways, it is important to know the capabilities of these consultants. Relying on a consultant for a portion of the emergency airway management process can be problematic for three reasons. First, the consultant might not be immediately available 24 hours/day, with obvious implications. Second, the consultant might not have the experience or skill that you expect. For example, many anesthesiologists do not have significant experience in awake intubation in the emergency setting. Some surgeons are not familiar with the tactile approach to emergency cricothyrotomy and may instead try in vain to visualize anatomic structures or may request unavailable equipment. Third, the operator might have technical skill but may not be experienced in the decision-making for emergency airway management, including use of RSI, EGDs, and deciding when to perform a surgical airway. If a consultant who does not normally perform ED intubations is assisting with the intubation procedure, decision-making must remain with the primary team. Perfect communication as to timing of rescue techniques is essential.

TAKING OWNERSHIP, CONTINUOUS QUALITY IMPROVEMENT, AND THE AIRWAY LEAD

There are less tangible factors that also contribute significantly to the success and safety of emergency intubation for both individuals and departments. Departments that have a culture of complete ownership of emergency intubation will feel and be more responsible for the procedure, which will, in turn and over time, increase the skill and confidence in the spectrum of decision-making and technical skill required. Individuals and departments should—when appropriately trained and experienced—commit to care for all patients who require intubation, not just those predicted to be

straightforward intubations. This will entail proficiency in laryngoscopy, rescue oxygenation with bag-mask devices and EGDs, performance of surgical airways, and awake endoscopic intubation, and the knowledge of when to perform each of these techniques. This knowledge and attitude will foster a culture of ownership for this procedure, allowing for more prompt, efficient, and safe emergency airway management.

It is common for departments to perform quality assurance on ultrasound images or other processes. We should perform these same activities for emergency intubation. Because emergency intubation is an inherently risky procedure in which small procedural changes or omissions of key steps can have large effects on the patient receiving care, continuous quality improvement is necessary to monitor patient outcomes. This will aid in determining whether there are systematic improvements that can improve the success and safety of this procedure within a department. Quality improvement processes will vary by department but should include, at a minimum, a record of the details of the procedure, its outcomes, and any complications, while allowing for specific comments from the clinical team. This could take many forms, ranging from inserting a simple paper form in a drop box for manual review to entry of sophisticated intubation data points into an electronic database. Without measuring these data points, it is nearly impossible to systematically improve them.

Finally, in each department that performs emergency airway management at least one person should be appointed to be the airway lead. This person will be responsible for staying current with airway literature, ensuring the department has appropriate airway devices and training, and reviewing the continuous quality improvement data to monitor procedural and patient outcomes. The airway lead’s goal is to achieve first attempt success >95% while continually decreasing intubation-associated complications. Identifying one or two people to serve in this role, rather than diffusing responsibility, serves to concentrate responsibility for these important tasks and allow truer accountability.

SUMMARY

Emergency intubation is a complex and potentially risky procedure. It can be made simpler and safer by using a standard approach that uses the best

available techniques, equipment, and personnel for each intubation. To achieve the highest success with the fewest complications, departments should continually monitor intubation outcomes to identify areas for incremental improvement.

EVIDENCE

What are estimates of first attempt intubation success in various settings?

A large meta-analysis, published in 2017, including ED studies published from 2000 to 2016 from all over the world demonstrated an average first attempt success rate of 84.1%.[1] However, contemporary data from ED registries show an average first attempt success rate of about 90%, with success within sites participating in the ED registry varying from 77% to 97%.[2,3] First attempt intubation success in ICUs, with a different patient population, has varied from about 70%[4,5] to 80%.[6,7]

How important is first attempt success?

Multiple studies, across diverse geographic areas, medical specialties, hospital units (ED and intensive care unit), and patient populations have shown that first attempt success is associated with a decreased risk of hypoxemia, aspiration, cardiac arrest, and other peri-intubation complications.[1,7–12]

Can checklists, bundled initiatives, and a continuous quality improvement program improve first attempt intubation success?

Yes, there are several studies showing that implementation of a continuous quality improvement (CQI) program, including checklists and bundled changes, is associated with significant improvement in first attempt success rate for emergency intubation.

Sakles et al. described how a comprehensive CQI program over a 10-year period improved first attempt intubation success in a busy academic ED, from 73% to 92%.[13] Groombridge et al. showed that implementation of an airway bundle including an airway registry, monthly airway audit sessions, and an RSI checklist, resulted in improvement in first attempt intubation success from 89% to 95%.[14] Fogg et al. found that by implementing a bundle of changes spanning the domains of staff training, equipment, and

practice standardization, they were able to improve their first attempt success rate from 83% to 94%.[15] Kerrey et al. initiated a CQI program in a high-volume academic pediatric ED, which included a checklist with formal execution process, mandatory use of video laryngoscopy (VL), and restrictions on novice intubators, and reported a significant reduction in intubation-associated hypoxemia from a historical control of 33% to 16%.[16]

What specific changes were common among groups that implemented changes and improved first attempt intubation success?

- Use of a preintubation checklist[14–16]
- Optimization of preoxygenation and apneic oxygenation[13–16]
- Increased use of videolaryngoscopy with standard geometry (Macintosh) blades—which allow both direct laryngoscopy (DL) and VL simultaneously[13–16]
- Increased use of a bougie or stylet[14,15]
- Decreased incidence of novices attempting emergency intubation[15,16]

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CHAPTER 24

Anesthesia and Sedation for Awake Intubation

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INTRODUCTION

Humans protect their airway at any cost. It is extremely difficult to adequately visualize the glottis with a laryngoscope in a fully awake and aware patient with intact protective airway reflexes. Rapid sequence intubation (RSI) is effective in producing intubating conditions because it renders the patient cooperative, amnestic, and unaware while disabling the efferent limb of these protective reflexes. An alternative pharmacologic strategy may be deployed to produce intubating conditions while avoiding precipitating an airway crisis in patients with physiologic fragility or anatomic challenges, particularly when reoxygenation with bag-mask ventilation (BVM) or a supraglottic device is predicted to be difficult.

Awake methods of intubation are intended to maintain ventilatory drive during the procedure and reduce the physiologic consequences of induction. These techniques rely on local anesthesia to facilitate instrumentation of the airway by attenuating the afferent limb of protective airway reflexes and on titrated procedural sedation to render the patient cooperative. Generally, local anesthesia is the most important component and is optimized first to limit potential untoward effects of systemic sedation.

INDICATIONS AND CONTRAINDICATIONS

Awake laryngoscopy has two common goals. Both are applicable to patients with difficult intubation features.

Glottic Visualization

Local airway anesthesia facilitates visualization of the hypopharynx and glottis for diagnostic or prognostic purposes. Common indications include examination for hoarseness, stridor, hemoptysis, suspected foreign body or mass, inhalation injury, or neck trauma. In many cases, the need for intubation is not clear, and visual examination helps determine the need for a definitive airway as well as the presence of anatomic limitations. This is a common practice in burn patients who might have suffered a thermal airway injury. If edema is present or symptoms are progressive, intubation is warranted. If swelling is minor or nonexistent and patient symptoms seem stable, then close observation in an intensive care unit, without intubation, can be a reasonable approach. A diagnostic awake evaluation of the airway is typically performed using a flexible endoscope inserted through a nostril or the mouth. The latter can be accomplished by having an assistant hold the patient's tongue out of the mouth using folded gauze. The scope is then advanced over the base of the tongue and the flexible tip deflected downward to quickly visualize glottic and periglottic anatomy. This can often be performed quickly with topical nasal or oral anesthesia only. When intubation is anticipated, it is helpful to preload a 6-0 or 6-5 endotracheal tube (ETT) in the nostril or through an oropharyngeal adjunct (eg, a Williams or Ovassapian airway). The scope can then be passed through the ETT en route to the glottic inlet. This allows intubation to proceed, if needed, during the initial evaluation without having to withdraw and start anew.

Awake Intubation

The second common indication for an awake technique is when intubation is required but the situation prioritizes maintenance of spontaneous breathing and airway patency during the procedure. An awake method is considered when full induction, paralysis, and apnea are thought to be contraindicated. Predicted difficult glottic visualization based on assessment of external anatomic markers (eg, LEMON), concern about immediate desaturation with onset of apnea, or cardiovascular abnormalities that render induction an independent risk factor for circulatory collapse are common examples (see Chapter 4).

In all these situations, the degree of perceived difficulty and the decision to use RSI versus an awake approach depend on patient characteristics, the experience and judgment of the airway manager, and the available equipment. The only contraindication to an awake strategy is the need for immediate intervention for a rapidly deteriorating airway where time is insufficient to permit preparation (see Chapter 5, discussion of the "forced to act" scenario). Adequate time and patient cooperation are the most important limitations to awake airway visualization. A critical element of patient preparation is management of secretions or blood, which may thwart efforts to effectively anesthetize the airway, and attempts to visualize the glottis by endoscopy or blade laryngoscopy.

LOCAL ANESTHESIA FACTORS

Local anesthesia of the airway may be achieved topically, by injection, or by combining both techniques. The selection of a local anesthetic agent depends on the properties of the agent and how it is supplied (concentration and preparation—aqueous, gel, or ointment). Potent local anesthesia may enable the airway to be visualized with little or no sedation. As a general rule, local anesthesia should be optimized before any sedation is given to a high-risk patient selected for an awake technique.

Airway secretions interfere with topical anesthesia by diluting applied agents or washing them away from the intended target. Antisialagogues are effective adjuncts to reduce secretions and thereby improve topical anesthesia and visualizing conditions. The antimuscarinic agent glycopyrrolate (Robinul) is the preferred agent (0.005 mg/kg: usual adult dose 0.2-0.4 mg IV). The greatest drawback to its use is time to effective drying, which is 10 to 20 minutes following IV administration. Still, given sufficient time, even if only 10 minutes are available, glycopyrrolate should be given to facilitate topical anesthesia and improve the glottic view. It is important to realize that antisialagogues attenuate only secretions that are elaborated after the onset of their intended action. Extant secretions that may interfere with topical anesthesia or glottic view must be removed by suction, mechanical wiping, or effective patient cough and swallowing. The need for suction should always be anticipated and a suction catheter readied for use before airway topicalization. Patient tolerance of subsequent

suctioning is useful evidence of adequate topicalization prior to further instrumentation of the airway.

Lidocaine remains a favored drug for airway anesthesia because of its rapid onset (2-5 minutes to peak effect), useful duration (15-90 minutes), safety, and widespread availability. Concentrations of 2% (20 mg/mL) to 4% (40 mg/mL) aqueous solutions are optimal for topical use, with higher concentrations producing more rapid anesthesia. The addition of epinephrine provides no advantage.

Lidocaine applied to mucous membranes is incompletely absorbed into the systemic circulation. Serum levels after topicalization vary widely between individuals and are influenced by antisialagogue usage, method and timing of application, extremes of age, circulatory status, body habitus, liver disease, and the condition of the mucosal target (normal vs inflamed). Lidocaine applied to the supraglottic airway and swallowed is eliminated by first-pass metabolism in the liver and does not contribute to systemic toxicity. Serum levels and applied dosage correlate poorly with clinical toxicity, but the level at which toxicity first occurs is generally considered to be 5 μg/mL. Serum levels may not peak for 20 minutes to an hour after mucosal application. Intravenous dosage guidelines are excessively conservative when lidocaine is to be administered by aerosol or sprayed through an endoscope. We recommend a maximum topical lidocaine dose of 4 to 5 mg/kg (280-350 mg in a 70 kg individual; 7-8.75 mL of 4% aqueous solution). With careful administration, this should be more than sufficient to provide effective airway topicalization for nasotracheal or orotracheal awake intubation. The maximum dose should be calculated based on lean body weight (LBW) before administration, and the cumulative dose should be monitored during use. Different centers have advocated maximum safe infiltrative dosages of 5 mg/kg without epinephrine and topical dosages from 4 to 9 mg/kg. There are no studies that systematically evaluate topical mucosal anesthesia in the emergency department population. Clinical judgment is required, and meticulous attention to detail is necessary when lidocaine is applied to the airway to achieve effective anesthesia without producing toxicity.

Aerosolization of aqueous lidocaine is effective when the droplet size produced favors delivery of the drug to the supraglottic mucosa. Gas-powered nebulizers, as used for bronchodilator therapy, may be useful as a

first step to initiate topical airway anesthesia. However, nebulizers are designed to deliver small particle aerosols that primarily reach the tracheobronchial tree, where they will not contribute to anesthesia of the upper airway. Further, lidocaine is well absorbed from the trachea and distal subglottic airways, increasing the potential for systemic toxicity. Lastly, a large but variable fraction of nebulized lidocaine is exhaled with each breath, complicating estimates of the delivered dose. In comparison to nebulizers, atomizers produce larger droplets that tend to plate out on the supraglottic mucosa, providing more rapid, effective, and targeted anesthesia for upper airway instrumentation. Commonly available, effective devices for local anesthetic atomization are shown in **Figure 24.1**. An endoscope configured to allow spraying of lidocaine through the working channel is shown in **Figure 24.2**.

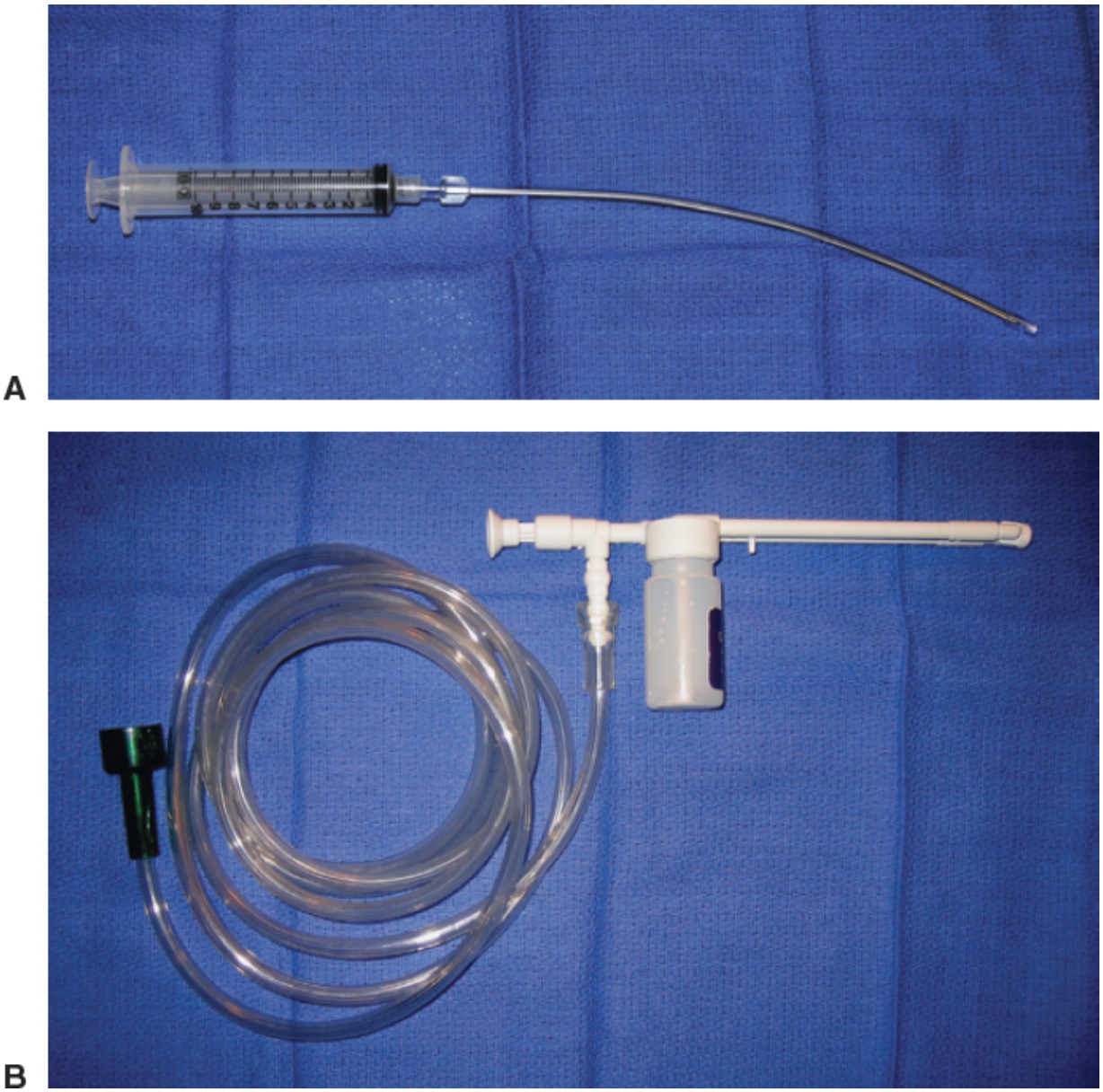

Figure 24.1: Mucosal atomization devices. A: A flexible, wire-directable atomization cannula that attaches to any Luer-lock or whistle-tip syringe. The syringe forces the local anesthetic solution through the atomizing tip, resulting in a fine mist. This can be synchronized with inspiration for general supraglottic distribution or aimed at specific airway structures for targeted mucosal anesthesia. B: A gas-powered atomizer with a nondirectable wand that produces an anesthetic mist by attaching to wall oxygen or to a separate air pump.

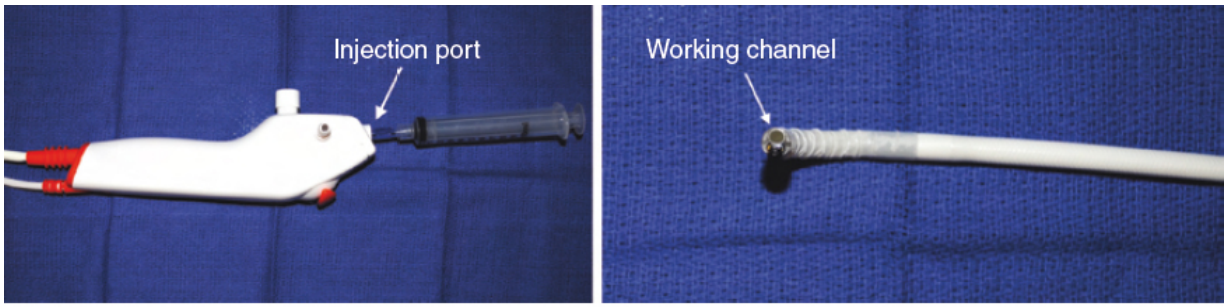

Figure 24.2: A: Endoscope handset with an anesthetic syringe attached to the injection port. B: Opening of the working channel at the endoscope tip allowing targeted injection of anesthetic under visual direction.

In addition to aqueous formulations, topical lidocaine is available as an ointment or gel in concentrations varying from 2% to 5%. Combinations of these formulations are often warranted, with attention paid to the cumulative contribution of each to the total administered dose (see **Fig. 24.3**).

Figure 24.3: Lidocaine preparations suitable for topical mucosal anesthesia of the airway. A: 50 mL bottle of 4% aqueous lidocaine. B: Tube of 5% lidocaine water-soluble ointment.

C: Cup containing 2% lidocaine gel.

Nasal Anesthesia

Almost a quarter of nasal intubations are complicated by bleeding. Topical vasoconstriction improves nasal passage caliber and may prevent epistaxis. Although evidence for this practice is not strong, there is little downside and generally no contraindication to use. Phenylephrine (Neo-Synephrine) 0.5% to 1.0% or oxymetazoline (Afrin) 0.05% sprayed and sniffed into each nostril 2 to 3 minutes before application of local anesthesia should allow adequate time for clinical effectiveness. Virtually all local anesthetic agents are effective when used topically in the nose. Cocaine 4% (40 mg/mL) and tetracaine 0.45% are particularly effective because of their tissue penetration and ability to eliminate deep pressure discomfort commonly associated with nasal manipulation. However, cocaine is associated with a higher risk of cardiovascular complications than other available alternatives. Lidocaine (discussed previously) is an effective nasal anesthetic, although it is associated with burning dysesthesia during application and may produces less dense anesthesia than cocaine or tetracaine. Regardless, lidocaine is the most frequently used agent for airway topicalization, including anesthesia of the nasal cavity.

Commonly used techniques for focused nasal anesthesia include the following:

- Atomize 1 to 3 mL of 4% aqueous lidocaine directly into the nostril while asking the patient to sniff deeply. Occlusion of the opposite nare may also be performed to aid with drug distribution to the posterior nasopharynx.
- Inject lidocaine gel or ointment (2-4 mL) into the nare with a small syringe while asking the patient to sniff. These formulations can also be applied to the mucosa of the inferior nasal meatus using a cotton-tipped applicator or through insertion of a coated nasopharyngeal airway. If intubation is planned, an ETT can be inserted with lidocaine applied to the outer surface of its distal portion.

Oral Anesthesia

Topical anesthesia of the oral cavity focuses on the tongue to attenuate the gag response and reduce the discomfort associated with its manipulation (eg, grasping the tongue with gauze and pulling to draw it and the epiglottis forward during endoscopy).

- Cooperative patients may be asked to gargle and swish with lidocaine 2% or 4% aqueous solution. Gargling also augments anesthesia of the oro- and hypopharynx.
- An atomizer can be used to spray aqueous lidocaine on tongue, palate, palatopharyngeal arches, and oropharynx in a targeted fashion. This method deserves particular attention because patients in any degree of respiratory distress may be unable to gargle or protrude their tongue effectively. Swelling or upward and backward displacement of the tongue (as in angioedema or a sublingual mass) may interfere with "buttering the tongue" with topical anesthetic (see later). A flexible, directable mucosal atomizer (MADgic device, LMA North America, San Diego, CA) may prove superior to other methods when access to the oral cavity and oropharynx is limited or when respiratory discomfort reduces the patient's ability to cooperate. If a combination of atomized lidocaine and lidocaine ointment is used, atomization should precede application of the ointment, because ointment will prevent aqueous lidocaine from reaching the mucosa.
- "Butter the tongue" with 3 to 4 cm of 5% lidocaine ointment (equivalent to 60-80 mg) applied to the posterior base of the protruded tongue with a tongue depressor. Maintain the mouth open and tongue protruded for several minutes to allow the formula to melt and spread on the base of the tongue, lingual tonsil, and oropharynx. Manual control of the tongue with gauze while asking the patient to "pant like a dog" facilitates this maneuver.

Oropharyngeal and Hypopharyngeal Anesthesia

The major sensory supply to the oropharynx and hypopharynx is the glossopharyngeal nerve (see Chapter 7). Although cooperative patients can gargle anesthetic to initiate the process, the best way to achieve dense local anesthesia of these regions for airway instrumentation is a nerve block at

the base of the palatopharyngeal arch (posterior tonsillar pillar; see Fig. 7.3). The following four techniques are commonly used:

- *Injection technique*: A 22G to 25G long needle with 1 cm of exposed needle tip is inserted 0.5 cm behind the midpoint of the posterior tonsillar pillar and directed laterally and slightly posteriorly (see **Fig. 24.4**). Two milliliters of 2% lidocaine is infiltrated following a negative needle aspiration. Although this block is highly effective, it is not widely used because of the proximity of the carotid artery and risk of carotid injection (up to 5%). It is also highly dependent on patient cooperation.

Figure 24.4: Glossopharyngeal nerve block. Insertion point for a 22G to 25G long needle.

- *Pledget technique*: A cotton pledget is saturated with 4% aqueous lidocaine and applied for several minutes to the lower portion of the posterior tonsillar pillar with right-angled Jackson forceps. This method is also highly dependent on patient cooperation and unimpeded access to the posterior tonsillar pillar.
- *Topical ointment technique*: The "butter the tongue" technique mentioned earlier provides effective anesthesia for hypopharyngeal structures. The ointment liquefies as it warms and runs down the base of the palatopharyngeal arches to penetrate the mucosa and reach the glossopharyngeal nerve. Distribution to the valleculae, epiglottis, and pyriform recesses provides additional direct topical anesthesia and may block the internal branch of the superior laryngeal nerve, providing laryngeal anesthesia. Although effective, this method requires approximately 10 minutes for the ointment to melt and distribute to the relevant structures and depends on the ability of the patient to protrude their tongue during that interval.
- *Topical atomization technique*: A MADgic device is attached to a 10 mL syringe containing 4 to 10 mL of lidocaine 4% (depending on LBW). The base of the tongue, soft palate, tonsillar pillars and posterior oropharynx are sequentially sprayed. After 30 seconds, the distal portion of the wire-directed, flexible wand of the atomizer is bent at 90°, passed into the oropharynx, and rotated so the tip points downward toward the hypopharynx and glottic inlet. The epiglottis, vallecula, pyriform recesses, vestibule, and vocal cords (heralded by coughing) are then blindly sprayed (see **Fig. 24.5**).

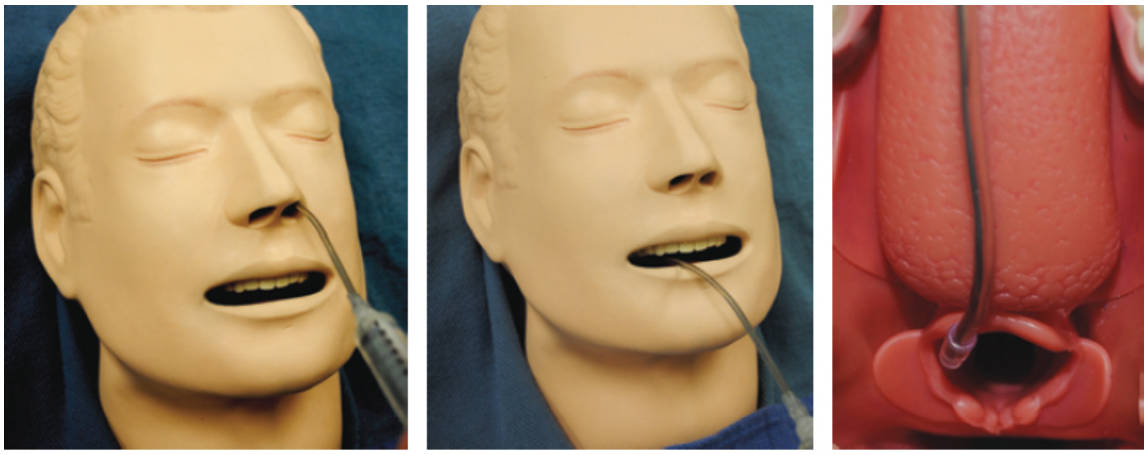

Figure 24.5: A: Aqueous lidocaine being sprayed with a wire-directable mucosal atomizer into the inferior meatus of the nasal cavity. B: Mucosal atomizer spraying lidocaine into the oral cavity and oropharynx. C: Mucosal atomizer in position to spray aqueous lidocaine into the hypopharynx and glottic vestibule.

Laryngeal Anesthesia

Topical anesthesia of the larynx can be accomplished using an atomizer or the working channel of an endoscope (spray-as-you-go technique) to deliver 2 to 4 mL of 4% aqueous lidocaine. Atomization is more rapid and effective, but spraying through the endoscope under direct vision allows targeted application to the glottic vestibule and vocal cords. Alternatively, the internal branch of superior laryngeal nerve can be blocked either internally or externally (see Fig. 7.6).

- The internal branch of the superior laryngeal nerve can be blocked topically by the methods described previously, or by using Jackson forceps to hold a cotton pledget soaked in 4% lidocaine against the mucosa just deep to the pyriform recesses for 1 minute. Emergency indications for awake intubations often make this step impractical or impossible owing to airway pathology, patient acuity, or both.
- An infiltrative block can also be performed using an external approach to the nerve as it perforates the thyrohyoid membrane just below the greater cornu of the hyoid bone. Infiltrative block with 3 mL of 2% lidocaine through a 21G to 25G needle produces very effective laryngeal anesthesia. However, this method is rare in emergency medicine and should *not* be performed by practitioners unfamiliar with

the regional anatomy or inexperienced in the technique. Serious potential complications include carotid arterial injection and compressive airway hematoma.

Tracheal Anesthesia

The trachea is best anesthetized topically. Local anesthetic agents can be sprayed into the trachea through an atomizer or endoscope channel, as described previously. Topical anesthesia of the upper tracheal and larynx can be accomplished by injection through a cricothyroid puncture.

- A syringe containing 3 mL of 4% aqueous lidocaine is attached to a 20G IV catheter-over-needle device. A small area of skin is anesthetized over the cricothyroid membrane using a 25G to 27G needle. The needle-cannula is then inserted into the trachea while aspirating for air. Once the air column is entered, the plastic cannula is advanced over the needle into the trachea. The needle is withdrawn and discarded. Lidocaine is injected at end expiration with the subsequent inspiration and cough facilitating downward and upward spread of anesthetic.
- *Spray-as-you-go technique*: Aqueous lidocaine is applied under direct visual guidance through the working channel of an endoscope. This method is less invasive than cricothyroid puncture and is of particular value as an adjunct to atomized topical anesthesia, allowing targeted application to the trachea and glottic inlet just before passing the endoscope and tracheal tube through these densely innervated structures.

SEDATION TECHNIQUES

Awake laryngoscopy during an emergency airway situation may require titration of small amounts of systemic sedation to supplement topical anesthesia. Administer only the amount of sedation required for patient cooperation and procedural tolerance. Deep anesthesia defeats the fundamental purpose of an awake approach to maintain spontaneous ventilation and is equivalent to a “sedation only” intubation attempt. These are fraught with complications, including apnea and airway collapse, and

should be avoided. A variety of sedative-hypnotic medications may be used, including midazolam, propofol, etomidate, and ketamine. Agent selection depends on the clinical situation, medication availability, and the experience of the airway manager with each drug. To reduce the cognitive load, it is generally best to achieve sedation for airway examination by familiar methods used for other painful or uncomfortable procedures.

All agents classified as sedative-hypnotics cause respiratory depression in a dose-dependent fashion. This is also true of opioids such as fentanyl and morphine, particularly when used in conjunction with sedative-hypnotic agents. Fragile patients with compensated respiratory failure may be rendered critically bradypneic or apneic with relatively small doses of these agents. Sedatives and opioid analgesics also produce some degree of muscle relaxation, and patients with partial upper airway obstruction may progress to complete obstruction if these agents cause a loss of critical upper airway muscle tone. The operator should always be prepared to proceed directly to a surgical airway (ie, double setup situation) when sedation and local anesthesia are undertaken on a patient with partial or impending airway obstruction (see Chapter 37). Ketamine is a unique dissociative agent that maintains muscle tone and spontaneous respirations when used at low to moderate doses. Doses exceeding 1 mg/kg IV may invoke respiratory depression, and in patients with antecedent hemodynamic compromise or catecholamine depletion, cardiovascular depression may occur. Ketamine may also sensitize the larynx to laryngospasm in the face of laryngeal inflammation. The preservation of airway maintenance and spontaneous ventilation is important for this procedure, and ketamine is a preferred agent despite the need for these cautions. Ketamine should be titrated in 25 mg aliquots IV until the patient can tolerate an awake look. Even when fully dissociated, the patient generally continues to breathe spontaneously and maintain airway patency. Some authors advocate a combination of ketamine and propofol (ketofol) in the same syringe to make a concentration of 5 mg/mL of each (5 mL of 10 mg/mL ketamine plus 5 mL of 10 mg/mL propofol in a 10 mL syringe). Ketofol is titrated 1 to 2 mL at a time. Although this method administers two agents in a fixed combination, it appears to be effective and safe, and the two drugs are compatible in the same syringe. Whether ketamine or an alternative sedative is used,

continuous vigilance for airway patency and adequacy of ventilation is required.

Uncooperative or intoxicated patients may require chemical restraint before and during airway assessment and preparation. Haloperidol, a butyrophenone, is rapidly acting, and IV doses of 2 to 5 mg in the adult can be carefully titrated to effect at 3- to 5-minute intervals. If hypoxia or severe respiratory distress is the cause of the combative behavior, an awake technique is neither advised nor likely to succeed.

Two newer agents show promise for awake endoscopy during emergency situations. Remifentanil is an ultra-short-acting opioid with rapid onset and offset, both measured in tens of seconds rather than minutes. There is a wide range of recommended dosing, and a conservative starting dose should be considered. An IV bolus of 0.75 μg/kg may precede a continuous infusion at 0.05 to 0.1 μg/kg/min with subsequent titration to effect. Dosing should be calculated on LBW in morbidly obese patients and reduced by as much as 50% in the elderly. Anecdotally, remifentanil infusion appears to attenuate gag, cough, and laryngospasm and can thus augment topical airway anesthesia. This may be particularly useful in patients with a hyperactive gag reflex and in the presence of excess secretions that requiring suctioning.

Dexmedetomidine is an intravenous β_2-agonist indicated for induction of general anesthesia and sedation during critical illness. It possesses desirable properties for awake endoscopy, including rapid onset of hypnosis, analgesia, and amnesia without respiratory depression. Typical dosing is 1 μg/kg IV over 10 minutes, followed by infusion at 0.1 μg/kg/hr and titrated to effect. Supplemental doses of a second agent (eg, propofol) may be required. Bradycardia and hypotension are uncommon but important side effects. Although the 2018 American College of Emergency Physicians (ACEP) clinical practice guideline on unscheduled procedural sedation supports remifentanil and dexmedetomidine as appropriate drugs for emergency department sedation, monitoring requirements, individual hospital restrictions, and clinical familiarity may impact practical use of these agents.

TIPS AND PEARLS

Summary

- Effective topical anesthesia of the upper airways is most effective when the drug is applied to dry mucous membranes.
- For mucosal drying, we recommend glycopyrrolate (0.005 mg/kg IV) with a usual adult dose of 0.2-0.4 mg IV.
- Local anesthesia is first optimized in order to limit potential untoward effects of systemic sedation. Uncooperative or rapidly decompensating patients are exceptions where sedation may dominate over local anesthesia.
- The dissociated anesthesia and preserved respiratory drive produced with low to moderate dose IV ketamine (up to 1 mg/kg) make it a prime agent for awake airway procedures.
- Systemic sedation should be titrated with extreme caution in patients with impending airway obstruction, tenuous respiratory status, or hemodynamic compromise. In general, the lowest possible sedative dosage should be used, and agents and dosages with a lesser propensity for causing respiratory depression are favored.

EVIDENCE

What is the evidence for the maximum safe dosage of topical airway lidocaine to avoid local anesthetic systemic toxicity?

The evidence for this is not robust. Recommendations are largely based on case reports and small uncontrolled trials in the anesthesia and endoscopy literature. Trials in the emergency department setting are lacking. In an early endoscopy study, airway topicalization with lidocaine resulted in no clinical toxicity when administered in dosages from 2 to 17 mg/kg.[1] Only 2 of 84 patients developed serum levels that exceeded the commonly held toxic threshold (one receiving 12 mg/kg, the other 17 mg/kg). Other trials of airway endoscopy patients receiving an average delivered lidocaine doses of 8.8 to 9.3 mg/kg showed no evidence of significant clinical toxicity and no serum levels exceeding the toxic threshold.[2] In contrast, a

study in normal volunteers documented symptoms of systemic lidocaine toxicity in 37% although the administered dose was < 9 mg/kg.[3] Based on these and other trials, the Difficult Airway Society guideline for adult awake tracheal intubation recommends a maximum safe dosage for mucosally applied lidocaine of 9 mg/kg, but note that systemic toxicity has been reported with dosages as low as 6.3 mg/kg.[4] The guideline emphasizes that this dosage is a ceiling and not a recommended dosage to be commonly used. Effective topicalization of the airway can be accomplished with amounts well below these thresholds, forming the basis for the dosage recommendation (4-5 mg/kg LBW) given earlier.

Can local anesthesia of the upper airway cause airway obstruction?

In the presence of preexisting airway compromise, topical anesthesia and instrumentation can cause dynamic airflow obstruction with or without laryngospasm.[5,6] A retrospective evaluation of 1554 awake intubations reported airway compromise after local airway anesthesia to be rare, occurring in only 12 cases (0.008%).[7] Nonetheless, preparation for immediate surgical airway control is a necessity whenever an airway is topically anesthetized, particularly an airway that is inflamed, infected, or partially obstructed. In certain cases, awake cricothyrotomy or tracheostomy under local anesthesia is a reasonable option.

What is the evidence for dexmedetomidine use during awake airway procedures?

Rapid-onset hypnosis and amnesia without accompanying respiratory depression are primary sedation goals during awake airway maneuvers. Dexmedetomidine has a favorable pharmacologic profile in this regard, leading to its increasing application in patients with tenuous or difficult airways.[8] A growing number of case reports and trial evidence support the safety and efficacy of dexmedetomidine as a primary and/or sole hypnotic agent to facilitate awake endoscopic intubation.[9–11]

What is the evidence for the use of ketamine and propofol together to facilitate awake airway management?

Ketofol for procedural sedation has seen increasing use over the past decade.[12,13] The combination is theoretically advantageous to limit dose-

related adverse events of each individual agent if they were used alone at a higher dose. A recent prospective randomized trial in difficult airway patients undergoing endoscopic intubation showed similar efficacy and safety between ketofol and a combination of dexmedetomidine-propofol.[14] Patients receiving ketofol had a shorter time to intubation and required less rescue propofol to accomplish the procedure. Operator satisfaction with the sedative regimen was higher in the ketofol group than in the dexmedetomidine-propofol group.

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Section VI

Pediatric Airway Management

25 Differentiating Aspects of the Pediatric Airway
26 Pediatric Airway Techniques
27 The Difficult Pediatric Airway
28 Foreign Body in the Pediatric Airway

CHAPTER 25

Differentiating Aspects of the Pediatric Airway

Robert C. Luten
Nathan W. Mick

THE CLINICAL CHALLENGE

Airway management in the pediatric population presents many potential challenges, including age-related drug dosing and equipment sizing, anatomic variation that continuously evolves as development proceeds from infancy to adolescence, and the performance anxiety that invariably accompanies the resuscitation of a critically ill child. Clinical competence in managing the airway of a critically ill or injured child requires an appreciation of age- and size-related factors, and a degree of familiarity and comfort with the fundamental approach to pediatric airway emergencies.

The general principles of airway management in children and adults are the same. Medications used to facilitate intubation, the need for alternative airway management techniques, and the basic approach to performing the procedure are similar whether the patient is 8 or 80 years of age. Differences, where they occur, are most exaggerated in the first 2 years of life, after which the pediatric airway gradually develops more adultlike features.

In contrast to the case of adults, in which recognition and management of the difficult airway is a foundational skill to be mastered, the challenge in children is to develop comfort in managing the predictable differences in anatomy and physiology that occur during development. Developing airway skills and maintaining them is arguably easier in adults because there is ample opportunity during clinical practice, as opposed to pediatrics, where the paucity of sick children encountered during training and practice makes attaining the same level of comfort difficult to achieve. This chapter will review those differences with the aim of simplifying them and making the key skills more easily learned and maintained.

APPROACH TO THE PEDIATRIC PATIENT

General Issues

The cognitive burden on providers during a pediatric resuscitation is different than that in adults owing to the unique anatomic and physiologic variables inherent in children. Age- and size-related variables unique to children introduce the need for more complex, nonreflexive, or knowledge-based mental activities, such as calculating drug doses and selecting equipment. The concentration required to undertake these activities while under stress may detract from other important mental activities such as assessment, evaluation, prioritization, and synthesis of information, referred to in the resuscitative process as critical thinking activities. The cumulative effect of these factors leads to inevitable time delays and a corresponding increase in the potential for decision-making errors during pediatric resuscitation. This is in sharp contrast to adult resuscitation, where drug doses, equipment sizing, and physiologic parameters are usually familiar to the provider, allowing for these decisions to be reflexive and thus freeing up the provider's attention for critical thinking. In children, drug doses are based on weight and may vary by an order of magnitude depending on age (ie, 3-kg neonate vs a 30-kg 8-year-old vs a 100-kg adolescent). The use of resuscitation aids in pediatric resuscitation significantly reduces the cognitive load (and error) related to drug dosing calculations and equipment selection by relegating these activities to a lower order of mental function (referred to as "automatic" or "rule based"). The results are reduced error, attenuation of psychological stress, and an increase in critical thinking time. **Table 25.1** is a length-based, color-coded equipment reference chart, based on the "resuscitation guide" of Broselow-Luten, for pediatric airway management that eliminates error-prone strategies based on age and weight. Both equipment and drug dosing information are included in the Broselow-Luten system and can be accessed by a single length

measurement or patient weight. This system is also available as part of a robust online resource (www.ebroselow.com).

TABLE 25.1 Equipment Selection

	Pink[a]	Red	Purple	Yellow	White	Blue	Orange	Green
Length (cm)-Based Pediatric Equipment Chart								
Weight (kg)	6-7	8-9	10-11	12-14	15-18	19-23	23-31	31-41
Length (cm)	60.75-67.75	67.75-75.25	75.25-85	85-98.25	98.25-110.75	110.75-122.5	122.5-137.5	137.5-155
ETT size (mm)	3.5 cuff 3.0 uncuff	3.5 cuff 3.0 uncuff	4.0 cuff 3.0 uncuff	4.5 cuff 4.0 uncuff	5.0 cuff 4.5 uncuff	5.5 cuff 5.0 uncuff	6.0 cuff	6.5 cuff
Lip-to-tip length (mm)	10-10.5	10.5-11	11-12	12.5-13.5	14-15	15.5-16.5	17-18	18.5-19.5
Laryngoscope size+blade	1 straight	1 straight	1 straight	2 straight	2 straight	2 straight or curved	2 straight or curved	3 straight or curved
Suction catheter	8F	8F	8F	8F-10F	10F	10F	10F	12F
Stylet	6F	6F	10F	10F	10F	10F	14F	14F
Oral airway (mm)	50	50	60	60	60	70	80	80
Nasopharyngeal airway	14F	14F	18F	20F	22F	24F	26F	30F
Bag/valve device	Infant	Infant	Child	Child	Child	Child	Child/adult	Adult
Oxygen mask	Newborn	Newborn	Pediatric	Pediatric	Pediatric	Pediatric	Adult	Adult
Vascular access	22-24/23-25	22-24/23-25	20-22/23-25	18-22/21-23	18-22/21-23	18-20/21-23	18-20/21-22	16-20/18-21
Catheter/butterfly	Intraosseous	Intraosseous	Intraosseous	Intraosseous	Intraosseous	Intraosseous		
Nasogastric tube	5-8F	5-8F	8-10F	10F	10-12F	12-14F	14-18F	18F
Urinary catheter	5-8F	5-8F	8-10F	10F	10-12F	10-12F	12F	12F
Chest tube	10-12F	10-12F	16-20F	20-24F	20-24F	24-32F	24-32F	32-40F
Blood pressure cuff	Newborn/infant	Newborn/infant	Infant/child	Child	Child	Child	Child/adult	Adult
LMA[b]	1.5	1.5	2	2	2	2-2.5	2.5	3

Directions for use: (1) measure patient length with centimeter tape or with a Broselow tape; (2) using measured length in centimeters or Broselow tape measurement, access appropriate equipment column; (3) column for ETTs, oral and nasopharyngeal airways, and LMAs; always select one size smaller and one size larger than recommended size.

ETT, endotracheal tube; LMA, laryngeal mask airway.

[a]*For infants smaller than the pink zone, but not preterm, use the same equipment as the pink zone.*

[b]*Based on manufacturer's weight-based guidelines:*

Mask Size	Patient Size (kg)
1	≤5
1.5	5-10
2	10-20
2.5	20-30

3	>30

Modified from Luten RC, Wears RL, Broselow J, et al. Managing the unique size related issues of pediatric resuscitation: reducing cognitive load with resuscitation aids. Acad Emerg Med. 1992;21:900–904.

Specific Issues

Anatomic and Functional Issues

The approach to the child with airway obstruction (the most common form of a difficult pediatric airway) incorporates several unique features of the pediatric anatomy.

1. Children obstruct more readily than adults do, and the pediatric airway is especially susceptible to airway obstruction resulting from swelling (see Chapter 27, which outlines the effect of 1-mm edema on airway resistance in the infant [4-mm airway diameter] vs the adult [8-mm airway diameter]). Nebulized racemic epinephrine causes local vasoconstriction and can reduce mucosal swelling and edema. For diseases such as croup, where the anatomic site of swelling occurs at the level of the cricoid ring, functionally the narrowest part of the pediatric airway, racemic epinephrine can have dramatic results. Disorders located in areas with greater airway caliber, such as the supraglottic region of epiglottitis or the retropharyngeal region of an abscess, rarely produce findings as dramatic. In clinical practice, efforts to force a nebulized medication on a child with epiglottitis may agitate the child, leading to increased airflow velocity and dynamic upper airway obstruction.
2. Noxious interventions can lead to dynamic airway obstruction and precipitate respiratory arrest. This has historically led to the admonition to “leave them alone” and allow the patient to assume a position of comfort. The work of breathing in the crying child increases 32-fold, elevating the threat of dynamic airway obstruction. Therefore, these children should be managed in a quiet, comfortable environment when presenting for upper airway obstruction (**Fig. 25.1A-C**).
3. Bag-mask ventilation (BMV) may be of particular value in the child with upper airway obstruction. Note in Figure 25.1C that efforts by the patient to alleviate the obstruction may exacerbate it, because increased inspiratory effort creates increased negative extrathoracic pressure, leading to collapse of the malleable extrathoracic trachea. The application of positive pressure through BMV can stent the airway open and relieve the dynamic component of obstruction (**Fig. 25.1C,D**). Thus, BMV is appropriate as a temporizing first maneuver if the patient arrests from obstruction. There have been numerous case reports of children with epiglottitis being successfully resuscitated utilizing BMV.

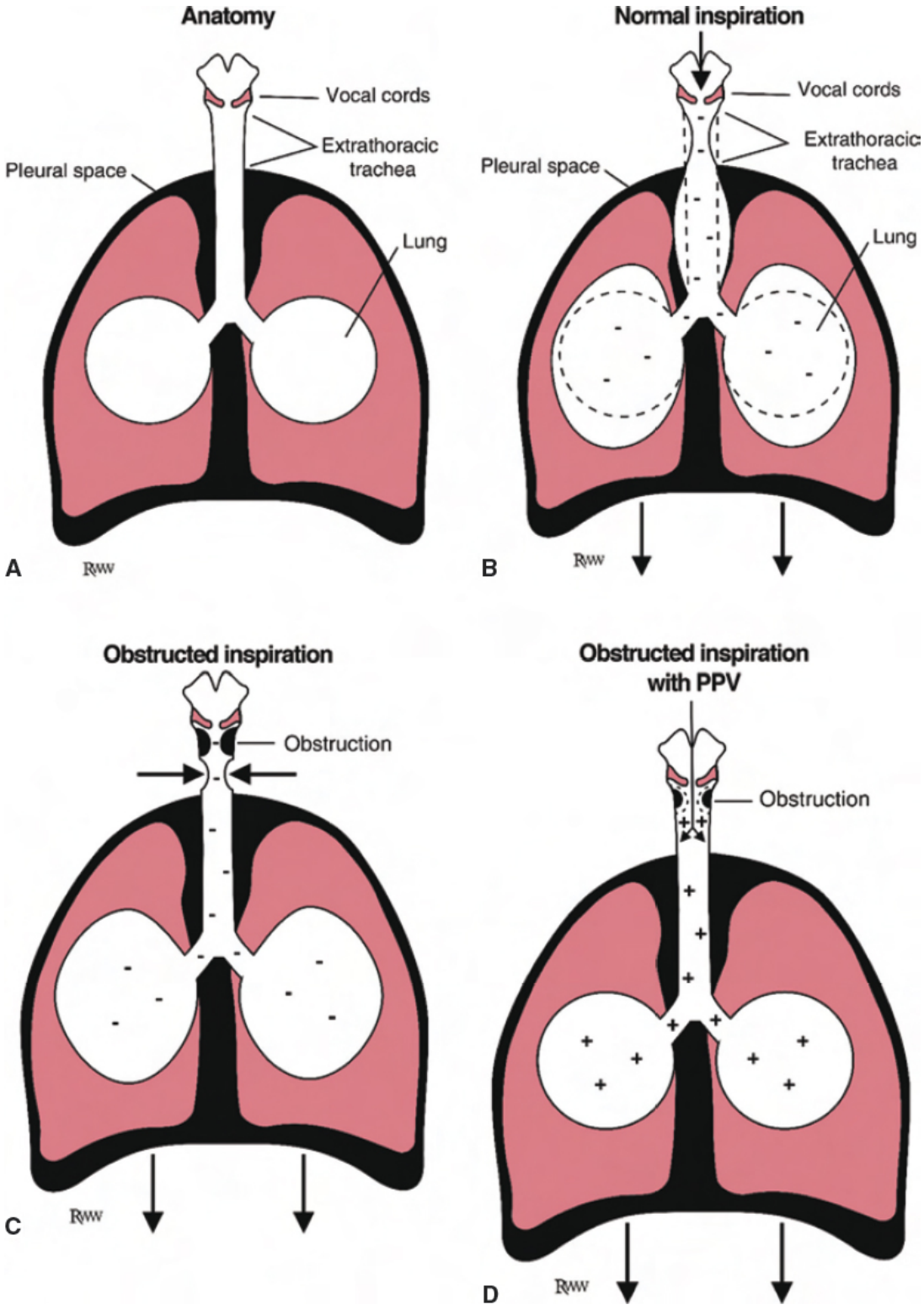

Figure 25.1: Intra- and extrathoracic trachea and the dynamic changes that occur in the presence of upper airway obstruction. A: Normal anatomy. B: The changes that occur with normal inspiration; that is, dynamic collapsing of the upper airway associated with the negative pressure of inspiration on the extrathoracic trachea. C: Exaggeration of the collapse secondary to superimposed obstruction at the subglottic area. D: Positive-pressure ventilation (PPV) stents the collapse/obstruction versus the patient's own inspiratory efforts, which increase the obstruction. (Redrawn from Cote CJ, Ryan JF, Todres ID, et al, eds. *A Practice of Anesthesia for Infants and Children.* 2nd ed. WB Saunders; 1993, with permission.)

4. Apart from differences related to size, there are certain anatomic peculiarities of the pediatric airway. These differences are most pronounced in children <2 years of age, whereas children >8 years of age are similar to adults anatomically and the 2- to 8-year-old period is one of transition. The glottic opening is situated at the level of the first cervical vertebra (C-1) in infancy. This level transitions to the level of C-3 to C-4 by age 7 and to the level of C-5 to C-6 in the adult. Thus, the glottic opening tends to be higher up in the neck in children as opposed to adults. The size of the tongue with respect to the oral cavity is larger in children, particularly infants, and the epiglottis is also proportionately larger, making efforts to visualize the airway without direct control more difficult. Thus, a straight (ie, Miller) blade, which is used to get underneath and directly elevate the epiglottis, is recommended in children younger than 3 years (**Table 25.2**).
5. Blind nasotracheal intubation is relatively contraindicated in children younger than 10 years of age. Children have large tonsils and adenoids, which may bleed significantly when traumatized, and the angle between the epiglottis and the laryngeal opening is more acute than that in the adult, making successful cannulation of the trachea difficult. Children also possess a small cricothyroid membrane, and in children younger than 3 to 4 years, it is virtually nonexistent. For this reason, needle cricothyrotomy may be difficult, and surgical cricothyrotomy is virtually impossible and contraindicated in infants and small children up to 10 years of age.
6. Although younger children possess a relatively high, anterior airway with the attendant difficulties in visualization of the glottic aperture, this anatomic pattern is consistent in all children, so this difficulty can be anticipated. The adult airway is subject to more variation and age-related disorders, leading to a difficult airway (eg, rheumatoid arthritis, obesity). Children are predictably "different," not "difficult." **Figure 25.2** demonstrates anatomic differences specific to children.

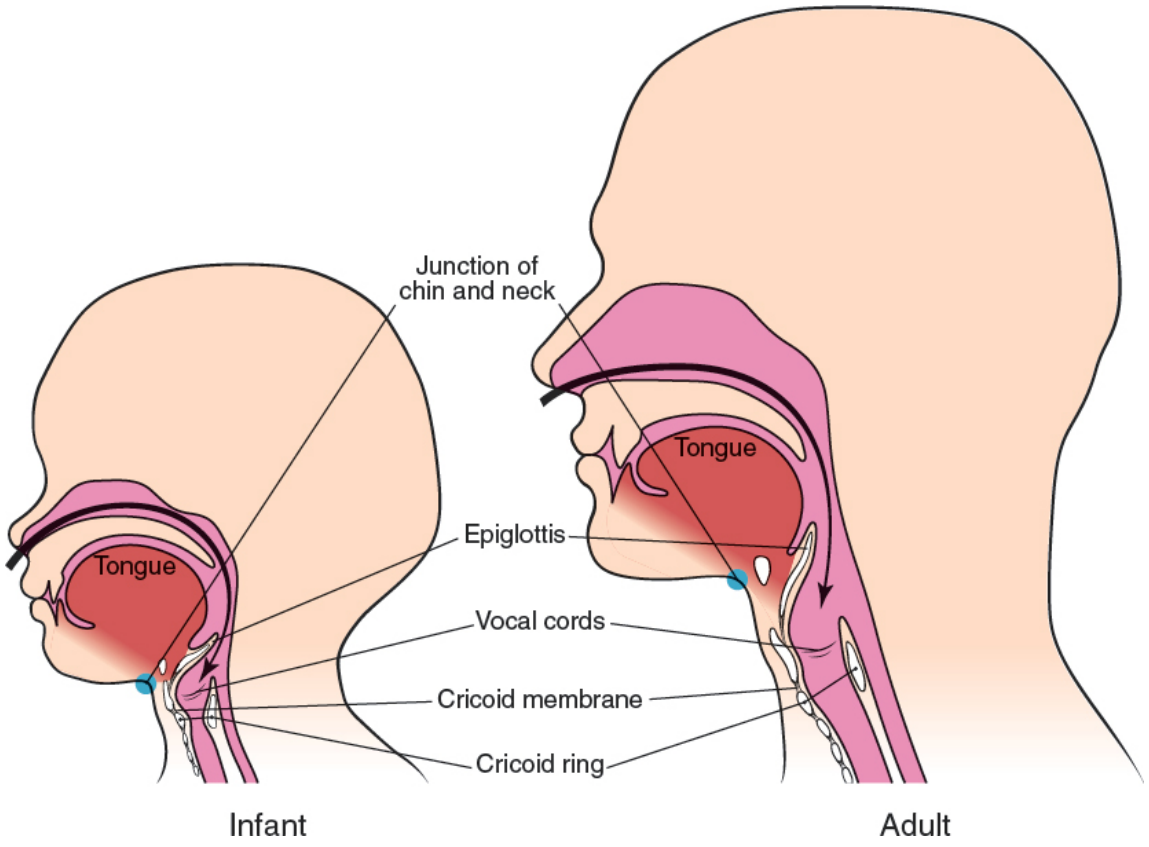

Figure 25.2: The anatomic differences specific to children are (1) higher, more anterior position of the glottic opening (note the relationship of the vocal cords to the chin/neck junction); (2) relatively larger tongue in the infant, which lies between the mouth and glottic opening; (3) relatively larger and more floppy epiglottis in the child; (4) the cricoid ring is the narrowest portion of the

pediatric airway versus the vocal cords in the adult; (5) position and size of the cricothyroid membrane in the infant; (6) sharper, more difficult angle for blind nasotracheal intubation; and (7) larger relative size of the occiput in the infant.

TABLE 25.2 Anatomic Differences Between Adults and Children

Anatomy	Clinical Significance
Large intraoral tongue occupying relatively large portion of the oral cavity and proportionally larger epiglottis	Straight blade preferred over curved to push distensible anatomy out of the way to visualize the larynx and elevate the epiglottis
High tracheal opening: C-1 in infancy vs C-3 to C-4 at age 7, C-5 to C-6 in the adult	High anterior airway position of the glottic opening compared with that in adults
Large occiput that may cause flexion of the airway, large tongue that easily collapses against the posterior pharynx	Sniffing position is preferred. The larger occiput actually elevates the head into the sniffing position in most infants and children. A towel may be required under shoulders to elevate torso relative to head in small infants
Cricoid ring is functionally the narrowest portion of the trachea as compared with the vocal cords in the adult.	Uncuffed tubes provide adequate seal because they fit snugly at the level of the cricoid ring. Correct tube size is essential because variable expansion cuffed tubes are not used. If using a cuffed tube, careful monitoring of cuff inflation pressure is essential.
Consistent anatomic variations with age with fewer abnormal variations related to body habitus, arthritis, chronic disease	Younger than 2 y, high anterior; 2-8 y, transition; and older than 8 y, small adult
Large tonsils and adenoids may bleed; more acute angle between epiglottis and laryngeal opening results in nasotracheal intubation attempt failures	Blind nasotracheal intubation not indicated in children; nasotracheal intubation failure
Small cricothyroid membrane landmark, surgical cricothyrotomy impossible in infants and small children	Needle cricothyrotomy recommended, and the landmark is the anterior surface of the trachea, not the cricoid membrane.

Physiologic Issues

There are two important physiologic differences between children and adults that impact airway management (**Box 25.1**). Children have a basal oxygen consumption that is approximately twice that of adults. Coupled with a proportionally smaller functional residual capacity (FRC) to body weight ratio, these factors result in more rapid desaturation in children compared with adults, given an equivalent duration of preoxygenation. Rapid desaturation is most pronounced in children < 24 months old. The clinician must anticipate and communicate this possibility to the staff and be prepared to provide supplemental oxygen by BMV if the patient's oxygen saturation drops below 90%.

BOX 25.1 Physiologic Differences

Physiologic Difference	Significance
Basal O_2 consumption is twice adult values (>6 mL/kg/min); proportionally smaller functional residual capacity as compared with adults	Shortened period of protection from hypoxia for equivalent preoxygenation time as compared with adults. Infants and small children often require bag-mask ventilation while maintaining cricoid pressure to avoid hypoxia.

Drug Dosage and Selection

The dose of succinylcholine (SCh) in children is different from that in adults. SCh is rapidly metabolized by plasma esterases and distributed to extracellular water. Children have a larger volume of extracellular fluid water relative to adults: at birth, 45%; at age 2 months, ~ 30%; at age 6 years, 20%; and at adulthood, 16% to 18%. The recommended dose of SCh, therefore, is higher on a per kilogram basis in children than in adults (2 vs 1.5 mg/kg). All drug dosage determinations are most appropriately and safely done using resuscitation aids such as the Broselow-Luten system previously described.

In 1993, the U.S. Food and Drug Administration (FDA), in conjunction with pharmaceutical companies, revised the package labeling for SCh in the wake of reports of hyperkalemic cardiac arrest following the administration of SCh to patients with previously undiagnosed neuromuscular disease. Initially, it stated that SCh was contraindicated for elective anesthesia in pediatric patients because of this concern, although the

wording was subsequently altered to embrace a risk-benefit analysis when deciding to use SCh in children. However, both the initial advisory warning and the revised warning continue to recommend SCh for emergency or full-stomach intubation in children. Pediatric drug doses are provided in **Table 25.3**.

TABLE 25.3 Drugs—Pediatric Considerations

Drug	Dosage	Pediatric-Specific Comments
Premedications		
Atropine	0.02 mg/kg	An option <1 y of age
Induction Agents		
Midazolam	0.3 mg/kg IV	Use 0.1 mg/kg if hypotensive
Etomidate	0.3 mg/kg IV	
Ketamine	2 mg/kg IV, 4 mg/kg IM	
Propofol	2-3 mg/kg IV	
Paralytics		
Succinylcholine	2 mg/kg IV	Have atropine drawn up and ready
Vecuronium	0.2 mg/kg IV	May increase to 0.3 mg/kg of vecuronium for RSI (0.1 mg/kg for maintenance of paralysis)
Rocuronium	1.0 mg/kg IV	For RSI

IM, intramuscularly; IV, intravenous; RSI, rapid sequence intubation.

Equipment Selection

Table 25.1 references length-based recommendations for emergency equipment in pediatric patients. Appropriately sized equipment can be chosen with a centimeter length measurement or with a Broselow tape.

A word of caution with respect to the storage of airway management equipment for children: Despite best efforts (eg, equipment lists or periodic checks), it is not uncommon for newborn equipment to be mixed in with or placed in proximity to the smallest pediatric equipment. This practice may lead to newborn equipment being used in older children for whom it may not be intended. Examples include the no. 0 laryngoscope blade, which is too short to allow visualization of the airway; the 250-mL newborn BMV, which provides inadequate ventilation volumes; and various other equipment, such as oral airways that can cause airway obstruction if too small (see **Table 25.4**).

TABLE 25.4 Dangerous Equipment

Equipment	Problem
No. 0 or no. 00 laryngoscope ETT blades	Valuable time can be lost trying to visualize the glottic opening if mistaken for a no. 1 blade.
Curved no. 1 laryngoscope blades	Straight blades are preferred because of the following: The epiglottis is picked up directly, not indirectly, by compressing the hyoepiglottic ligament in the vallecula. The tongue and mandibular anatomy are more easily elevated from the field of vision.
250-mL BMV	Cannot generate adequate tidal volumes
Cuffed ETTs <5.0 mm	If leak pressures are not monitored, ischemia of the tracheal mucosa may develop with the potential for scarring and stenosis.
Oral airways <50 mm	Unless appropriate size oral airways are used, they may act to increase, rather than relieve, obstruction.
Any *other* equipment too small	Sizing is critical to function!

Note: Only appropriate size is functional. Frequently, very small sizes are placed in the pediatric area without attention to appropriateness of size. This can greatly contribute to a failed airway outcome.

BMV, bag-mask ventilation; ETT, endotracheal tube.

Endotracheal Tubes

The correct endotracheal tube (ETT) size for the patient can be determined by a length measurement and by referring to the equipment selection chart. The formula (16 + age in years)/4 is also a reasonably accurate method of determining the correct uncuffed tube size. However, the formula cannot be used in children younger than 1 year and is useful only if an accurate age is known, although this cannot always be determined in an emergency. Either cuffed or uncuffed ETTs are acceptable in the younger pediatric age groups (**Fig. 25.3**). The admonition to avoid cuffed tubes in young infants is historical, and in the past, there was an unacceptably high rate of subglottic stenosis resulting from failure to carefully monitor cuff pressures. Newer ETTs make it easier to monitor cuff pressures and can be safely used in infants and small children, provided clinicians recognize the following fact: A cuffed tube adds 0.5 mm to the internal diameter (ID), so a smaller than predicted (by 0.5 mm) tube may be required. The cuffed tube should be inserted with the cuff deflated initially and inflated with the minimum volume of air needed for an adequate seal.

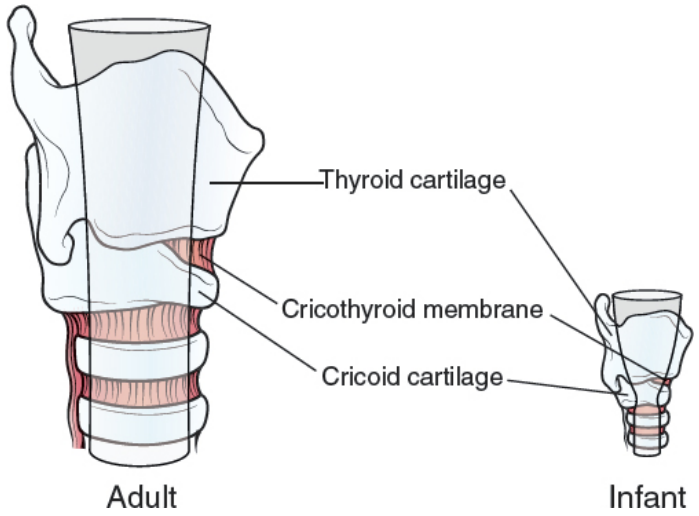

Figure 25.3: Airway shape. Note the position of the narrowest portion of the pediatric airway, which is at the cricoid ring, creating a funnel shape, versus the cylindrical shape seen in the adult, where the vocal cords form the narrowest portion. This is the rationale for using the uncuffed tube in the child; it fits snugly, unlike the cuffed tube used in the adult, which is inflated once the tube passes the cords to produce a snug fit. (Modified with permission from Cote CJ, Todres ID. The pediatric airway. In: Cote CJ, Ryan JF, Todres ID, et al, eds. *A Practice of Anesthesia for Infants and Children.* 2nd ed. WB Saunders; 1993.)

When intubating a young child, there is a tendency to insert the ETT too far, usually into the right mainstem bronchus. Various formulas can be used to determine the correct insertion distance (eg, tube size times 3; age/2 + 10). For example, a 3.5-mm ID tube should be inserted 3.5 × 3 = 10.5 cm at the lip. Alternatively, a length-based chart can be used. We recommend placing a piece of tape on the tube at the appropriate lip-to-tip centimeter line, which serves as a constant visual reminder of the correct position of the tip of the ETT in the intubated patient.

Tube-Securing Devices

Once an ETT has been successfully placed, take care to appropriately secure the tube at the mouth to prevent inadvertent dislodgement and extubation. Head and neck movement, particularly extension that translates into movement of the tube up and potentially out of the trachea, should be minimized. A cervical collar placed after intubation prevents flexion and extension and can therefore help prevent ETT dislodgement (**Fig. 25.4**). The ETT is traditionally secured by taping the tube to the cheek, although various commercial devices are also available.

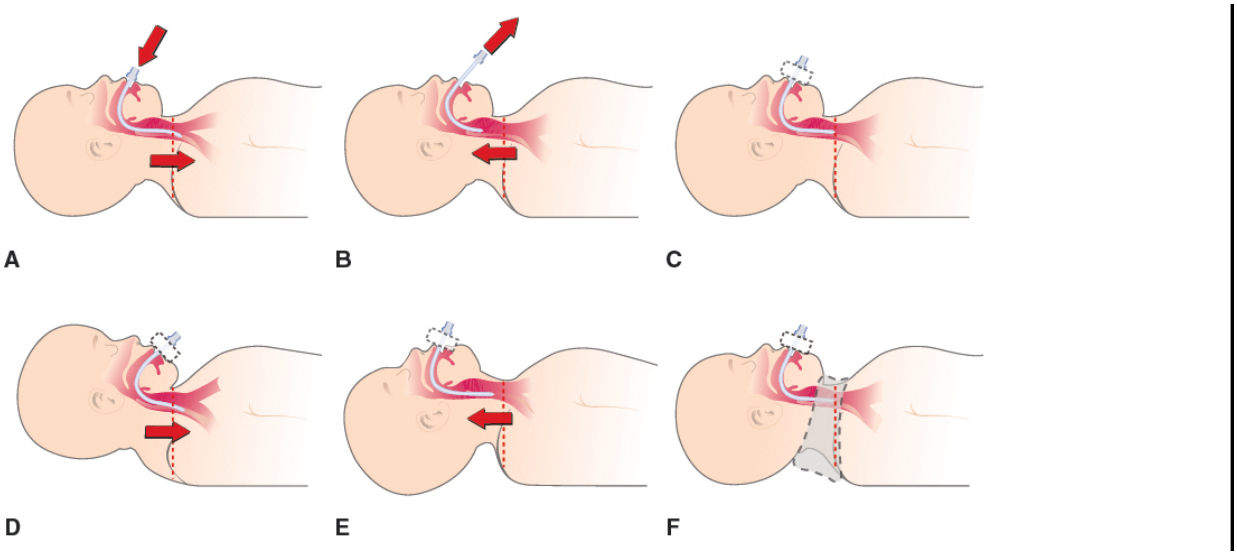

Figure 25.4: Securing the endotracheal tube. A: Unsecured tube sliding in/down. B: Unsecured tube sliding out/up. C: Tube secured to prevent in/out, up/down movement. D: Secured tube moving down and in as head flexes. E: Secured tube moving up/out as head extends. F: Neck movement prevented by cervical collar, thus preventing tube movement in the trachea.

Oxygen Masks

The simple rebreather mask used for most patients provides a maximum of 35% to 60% oxygen and requires a flow rate of 6 to 10 L/min. A non-rebreather mask can provide ~ 70% oxygen in children if a flow rate of 10 to 15 L/min is used. For emergency airway management, and particularly for preoxygenation for rapid sequence intubation (RSI), the pediatric non-rebreather mask is preferable. Adult non-rebreather masks can be used for older children but are too large to be used for infants and small children and will entrain significant amounts of room air. Apneic oxygenation (see Chapter 8) should be considered in children (at a rate of 1 L / min per year of age) as a low-risk maneuver to prolong safe apnea time. Recent evidence suggests that, in adults, turning the oxygen flow rate to the "flush" rate of 40 to 70 L/min (varies depending on the wall source) increases FIO_2 (>90%) and end-tidal oxygen measurements. This has not been studied rigorously in children but may be reasonable to try if preoxygenation is difficult. Additionally, properly configured bag-mask systems (ie, those that function as one-way inspiratory and expiratory valves and small dead space) are capable of delivering oxygen concentrations >90%, if correctly used. On inspiration, the spontaneously breathing patient opens the duck-billed inspiratory valve, and on expiration the expired volume with carbon dioxide (CO_2) pinches the duckbill valve closed and is vented through the expiratory valve into the atmosphere. One must be confident that the patient can generate sufficient negative inspiratory force to open the valve and draw a volume from bag; otherwise, bag assist is required. Adult-type units tend not to be used in infants and small children because of dead space considerations and size-related awkwardness, leading some to prefer pediatric non-rebreather BMV masks.

Oral Airways

Oral airways should be used only in children who are unconscious. In the conscious or semiconscious child, these airways can precipitate vomiting. Oral airways can be selected based on the Broselow tape measurement or can be approximated by selecting an oral airway that fits the distance from the angle of the mouth to the tragus of the ear.

Nasopharyngeal Airways

Nasopharyngeal airways are helpful in the obtunded but responsive child. The correctly sized nasopharyngeal airway is the largest one that comfortably fits in the naris but does not produce blanching of the nasal skin. The correct length is from the tip of the nose to the tragus of the ear and usually corresponds to the nasopharyngeal airway with the correct diameter. Care must be taken to suction these airways regularly to avoid blockage.

Nasogastric Tubes

BMV may lead to insufflation of the stomach, hindering full diaphragmatic excursion and preventing effective ventilation. Place a nasogastric (NG) tube soon after intubation to decompress the stomach in any patient who has undergone BMV and who requires ongoing mechanical ventilation after intubation. Often, in such patients, the abdomen is distended or tense, making the problem obvious, but other times it is difficult to identify the difference between this and the normally protuberant abdomen of the young child. Difficulty in ventilation that is felt to be related to reduced compliance should prompt the placement of an NG tube. Length-based systems identify the appropriate NG tube size.

BMV Equipment

For emergency airway management, the self-inflating bag is preferred by most over the anesthesia ventilation bag. These bag-mask units should have an oxygen reservoir so that at 10 to 15 L of oxygen flow, one can provide an F_{IO_2} of 90% to 95%. The smallest bag that should be used is 450 mL. Neonatal bags that are smaller (250 mL) do not provide effective tidal volume even for small infants. Many of the pediatric BMV devices have a positive-pressure relief (pop-off) valve. The pop-off valve may be set by the manufacturer to open anywhere between 20 and 45 cm H_2O pressure (centimeters of water pressure [CWP]), depending on whether the bag unit is intended for infants or small children (respectively), and is used to prevent barotrauma. The clinical scenarios encountered in emergency airway management often require higher peak airway pressures, so the bag should be configured without a pop-off valve or with a pop-off valve that can be closed. It is a good practice to store the BMV device with the pop-off valve closed so that initial attempts to ventilate the patient can achieve sufficient peak airway pressure to achieve ventilation. Chapter 26 discusses this issue in more detail and offers suggestions to prevent its occurrence.

End-Tidal CO_2 Detectors

Colorimetric end-tidal CO_2 ($ETCO_2$) detectors are as useful in children as in adults. A pediatric size exists for children weighing <15 kg, whereas the adult model should be used for children weighing >15 kg. If an adult-sized $ETCO_2$ device is used inappropriately for a small child, there may be insufficient CO_2 volumes to cause the detector to change color, resulting in a false-negative reading and removal of a correctly placed tube. Conversely, the resistance in a pediatric $ETCO_2$ detector may be sufficiently high to make ventilation difficult in a larger child.

Airway Alternatives

Orotracheal intubation is the procedure of choice for pediatric emergency airway management, including those patients with potential cervical spine injury where RSI with in-line manual stabilization is preferred. Nasotracheal intubation is relatively contraindicated in children **(Table 25.5)**.

TABLE 25.5 Alternatives for Airway Support

Bag-mask ventilation	May be the most reliable temporizing measure in children. Equipment selection, adjuncts, and good technique are essential.
Orotracheal intubation (usually with rapid sequence intubation)	Still the procedure of choice for emergent airway in potential cervical spine injury and most other circumstances
Needle cricothyrotomy	Recommended as last resort in infants and children, but data lacking
Laryngeal mask	Viable alternative
Blind nasotracheal intubation	Not indicated for children younger than 10 y
GlideScope	Well studied in adults, a potential alternative in children

Cricothyrotomy is the preferred emergency surgical airway in adults. The cricothyroid membrane develops in early childhood but is not of sufficient size to make it a viable rescue airway option until 10 years of age. “Needle cricothyrotomy” in children younger than 10 years is the term used when one accesses the airway in a percutaneous manner in young children, even though it is recognized that the point of entry into the airway is often the trachea as opposed to the cricothyroid space.

Other devices that may be of use in difficult airway management in young children are laryngeal mask airways (LMAs) and the GlideScope. LMAs are made for even newborns and young infants and may be useful as a temporizing measure when direct laryngoscopy proves difficult. The GlideScope is supplied in sizes appropriate for pediatric patients, although the penetration of this technology to all clinical settings has not occurred. These and other adjuncts are discussed in Chapter 26.

INITIATION OF MECHANICAL VENTILATION

In emergency pediatrics, two modes of ventilation are used. Pressure-controlled ventilation is the mode used for newborns and small infants, whereas volume-controlled ventilation is used for older children and adults. One can arbitrarily set 10 kg as the weight below which pressure-limited ventilators should be used, although volume-limited ventilators have been used effectively in smaller children. The younger the child is, the more rapid the ventilatory rate. The initial ventilatory rate in infants is typically set between 20 and 25 breaths per minute. Inspiratory:expiratory ratios are set at 1:2, and the typical peak inspiratory pressure at initiation of ventilation is between 15 and 20 CWP. These initial settings in a pressure-controlled ventilation mode will usually give a tidal volume of 8 to 12 mL/kg. These initial settings are adjusted according to subsequent clinical evaluation and chest rise. Positive end-expiratory pressure should also be set at 3 to 5 cm of water and F_{IO_2} at 1.0. The Broselow-Luten length-based system also provides guidance for approximate starting tidal volumes, ventilator rates, and inspiratory times.

Once initial settings have been established, it is critical that the patient be quickly reevaluated and adjustments made, particularly as pulmonary compliance, airways resistance, and leak volumes change with time, precluding adequate ventilation with the initial settings of pressure-controlled ventilation. Clinical evaluation of ventilatory adequacy is more important than formulae to ensure adequate ventilation. Once adjustments are made and the patient appears clinically to be ventilated and oxygenating, blood gas determinations, or continuous pulse oximetry and $ETCO_2$ monitoring, should be used for confirmation and to guide additional adjustments (**Table 25.6** and **Box 25.2**).

TABLE 25.6 Initiation of Mechanical Ventilation

I. Initial Settings		
Ventilator type	Pressure limited	Volume limited
Respiratory rate	20-25/min	12-20/min, by age
Positive end-expiratory pressure (cm H_2O)	3-5	3-5
F_{IO_2}	1.0 (100%)	1.0 (100%)
Inspiratory time	≥0.6 sec	≥0.6 sec
Inspiratory/expiratory ratio	1:2	1:2
Pressure/volume settings	For pressure ventilation, start with peak inspiratory pressure (PIP) of 15-20 cm H_2O. Assess chest rise and adjust to higher pressures as needed. For volume ventilation, start with tidal volumes of 8-12 mL/kg. Start at lower volumes and increase to a PIP of 20-30 cm H_2O. *These are initial setting guidelines only. Assess chest rise and adjust accordingly.*	
II. Evaluate Clinically and Make Adjustments	Most patients will be ventilated with volume- cycled ventilators. Poor chest rise, poor color, and decreased breath sounds require *higher* tidal volume. Check for pneumothorax or blocked tube. Ensure that tube size and position are optimal and leaks are not present. For patients ventilated with pressure-cycled ventilators, these findings may indicate the need to increase the PIP	
III. Laboratory Information	Arterial blood gas should be performed ~ 10-15 min after settings are stabilized. Additional samples may be necessary after each ventilator adjustment, unless ventilatory status is monitored by $ETCO_2$ and S_{PO_2}.	

BOX 25.2 Emergency Pediatric Airway Management—Practical Considerations

Anatomic
- Anticipate high anterior glottic opening
- Do not hyperextend the neck
- Uncuffed tubes are used in children younger than 8 y
- Use straight blades in young children

Physiologic
- Anticipate desaturation

Drug Dosage and Equipment Selection
- Use length-based system. Do *not* use memory or do calculations
- Nasogastric tube is an important airway adjunct in infants
- Stock pediatric non-rebreather masks

Airway Alternatives for Failed or Difficult Airway
- Surgical cricothyrotomy—contraindicated until age 10 y
- Blind nasotracheal intubation—contraindicated until age 10 y
- Combitube—only if >4 ft tall
- Needle cricothyrotomy—acceptable

TIPS AND PEARLS

RSI Techniques for Children

The procedure of RSI in children is essentially the same as in adults, with a few important differences outlined as follows:

- Preparation
  - Use resuscitation aids that address age- and size-related issues in drug dosing and equipment selection (eg, Broselow-Luten tape).
- Preoxygenation
  - Be meticulous. Children desaturate more rapidly than adults do.
  - Consider apneic oxygenation as an adjunct to maximize safe apnea time.
- Physiologic optimization
  - Weight-based isotonic fluid boluses or blood for hypotension. Maximize preoxygenation efforts. Consider atropine for infants <1 year of age.
- Paralysis with induction
  - Induction agent selection as for adult: dose by length or weight.
  - SCh 2 mg/kg IV or rocuronium 1 mg/kg.
  - Anticipate desaturation; bag ventilate if oxygen saturation (SpO_2) is <90%.
- Positioning with protection
  - Optional: apply Sellick maneuver.
- Placement with proof
  - Confirm tube placement with $ETCO_2$ as for adult.
- Postintubation management

In almost all cases, children who are intubated and mechanically ventilated should be sedated and paralyzed in the emergency department to prevent deleterious rises in intracranial or intrathoracic pressures and inadvertent ETT dislodgement.

EVIDENCE

Is lack of experience in managing pediatric airways a major problem for Emergency Providers?

Since the inception of Emergency Medicine as a specialty, there has been a concern over the amount of training emergency medicine residents received in pediatrics. Exposure to critically ill children is less common than exposure to critically ill adults in most training programs.[1,2,3] Introduction of the pneumococcal and *Haemophilus influenzae* vaccines, the change in sleep position that has reduced sudden infant death syndrome

deaths, and the overall improvement in pediatric care have further reduced ED visits for acute respiratory events. A recent article from a large children's hospital with >90 000 ED visits a year demonstrated insufficient exposure to critical procedures, especially intubations.[4] Informal surveys from the *Difficult Airway Course: Emergency* reveal that the emergency physician's experience and comfort with pediatric airways is a source of concern to many practitioners. It is hoped that the focused education and training in the airway course, and other high-quality simulation programs, can bolster comfort levels.[5]

What are the particular barriers to successful airway management in children?

Time delay and cognitive errors are more common with pediatric emergency airway management.[6] Pediatric emergencies are complicated by the fact that children vary in size, creating logistical difficulties, especially with respect to drug dosing and equipment selection. This mental burden (or "cognitive load") can be reduced by the use of resuscitation aids, which save time and reduce errors. The literature suggests that resuscitation aids can mitigate the effect of these variables on the mental burden in the resuscitative process.[7] Simulated emergency patient encounters have confirmed that the Broselow-Luten color-coded emergency system reduces time delay and errors by eliminating the cognitive burden associated with these situations.[8]

To the extent that the process can be simplified (eg, limiting the number of recommended medications, reducing the complexity and number of decisions required), time is freed up for critical thinking that can then be dedicated to the priorities of airway management. The management of children in extremis is inherently stressful, and, as such, RSI should be kept simple and uncomplicated to reduce this stress.

Should atropine be used for RSI in children?

The evidence does not support the universal use of atropine in children; however, it is an issue that is difficult to definitively resolve based on current literature. Traditionally, atropine has been used to prevent the bradycardia associated with a single dose of SCh in children, a rare but serious event. A few recent studies failed to show a difference in response to SCh with or without atropine in children,[9,10] with similar numbers in the atropine- and noratropine-treated groups developing transient, self-limited decreases in heart rate. The absence of evidence of benefit, however, should not be construed as "proof" when dealing with uncommon events. Atropine also has significant but rare side effects, including paradoxical bradycardia if incorrectly dosed.[11] Atropine may have a role when manipulating the airway of infants younger than 1 year because of their high vagal tone, coupled with a relatively greater dependency on heart rate for cardiac output.[12] However, most bradycardic episodes are because of hypoxia or are a transient, vagally mediated reflex response that resolves spontaneously. It is better to treat the hypoxia or the reflex if it occurs. To keep the process of RSI in children as simple as possible, we are not recommending the routine use of atropine. In special circumstances, such as with infants younger than 1 year (3, 4, and 5 kg, and pink or red zones on the Broselow-Luten tape and airway card), atropine can be considered optional.

SCh versus rocuronium as a paralytic in children—which is the preferred agent?

In the 1990s, the FDA warned against the use of SCh in children following case reports of hyperkalemic cardiac arrest following the administration of SCh to patients with undiagnosed neuromuscular disease. The pediatric anesthesia community at that time challenged the FDA decision based on the risk versus benefit in patients requiring emergency intubation, leading to a modification of their position to a "caution." There is no body of evidence that specifically addresses the relative risks and benefits of SCh versus rocuronium in children to guide recommendations. Currently, SCh remains the agent of choice for emergency full-stomach intubations, although both rocuronium and SCh should be considered viable options for emergency airway management of the pediatric patient based on provider preference.[13,14]

Are cuffed ETTs contraindicated in pediatric emergency airway management?

The issue of whether cuffed ETTs are safe or required in children younger than 8 to 10 years has been debated for some time because of the anatomic and functional seal afforded by the subglottic area. Two studies have addressed this issue.[15,16] Deakers et al. studied 282 patients intubated in the operating room, emergency department, or ICU.[15] In their observational prospective, nonrandomized study, they found no difference in postextubation stridor, the need for reintubation, or long-term upper airway complications. Khine et al.

compared the incidence of postextubation croup, inadequate ventilation, anesthetic gases leaking into the environment, and the requirement for a tube change resulting from air leak.[16] In this study of children younger than 8 years, the authors found no difference in croup, more attempts at intubation with uncuffed tubes, less gas flow required with cuffed tubes, or less gas leakage into the environment. Additionally, any large air leak in an uncuffed tube may require tube removal and replacement, which may not be the case with a cuffed ETT, where there is more "margin for error" in sizing afforded by the cuff. Even though it may seem that the use of cuffed tubes in younger children does not result in any postextubation sequelae, it must be made clear that these studies monitored cuff inflation pressures, a practice that is uncommonly performed in emergency intubations. For this reason, it seems reasonable to recommend the use of uncuffed ETTs to avoid excessive tracheal mucosal pressure with the potential sequelae of scarring and stenosis. However, for some patients in whom high mean airway pressures are expected, such as those with acute respiratory diseases and asthma, the placement of a cuffed tube with the cuff initially deflated, and inflated if necessary, may be appropriate. The most recent Pediatric Advanced Life Support standards recommend cuffed tubes, but with the qualifier *only if leak pressures are monitored*.[17]

Why do children desaturate more quickly than adults with comparable degrees of preoxygenation?

An infant uses 6 mL of oxygen/kg/min as compared with the adult who uses 3 mL/kg/min. The FRC reduction in an apneic child is far greater than in the apneic adult owing to differences in the elastic forces of the chest wall and the lung. In children, the chest wall is more compliant, and the lung elastic recoil is less than in adults. An analysis of these forces reveals that if they are brought into equilibrium as in the apneic patient, a value of FRC around 10% of total lung capacity is predicted instead of the observed value of slightly <40%. These same factors also reduce the FRC in the spontaneously breathing patient, albeit to a lesser degree. FRC is further reduced with the induction of anesthesia and by supine positioning. The clinical implication of the decreased effective FRC combined with increased oxygen consumption is that the preoxygenated, paralyzed infant has a disproportionately smaller reservoir of intrapulmonary oxygen to draw on as compared with the adult. Pulmonary pathology in critically ill patients may further reduce the ability to effectively preoxygenate. It is therefore critical that these factors be considered when preoxygenating a pediatric patient. BMV with cricoid pressure may be required to maintain oxygen saturation above 90% during RSI, especially if multiple attempts are required or the child has a disorder that compromises the ability to preoxygenate.[18,19]

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CHAPTER 26

Pediatric Airway Techniques

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INTRODUCTION

For the most part, the airway devices and techniques used in older children and adolescents are no different from those used in adults. Owing to their unique airway anatomy and a lack of commercially available rescue devices of appropriate size (eg, Combitube, LMA Fastrach), the same cannot be said of small children (younger than 3 years) and infants (younger than 1 year). We limit our discussion to those rescue devices that are available for the pediatric population *and* that have evidence of successful use in children. Mastering these techniques is straightforward and necessary if one is to manage the emergent pediatric airway.

TECHNIQUES USED IN ALL CHILDREN

Bag-Mask Ventilation and Endotracheal Intubation

Refer to Chapters 12 and 15 for a detailed description of bag-mask ventilation (BMV) and tracheal intubation. As in adults, nasopharyngeal and oral airways are important adjuncts to BMV, especially in small children in whom the tongue is relatively large in relation to the volume of the oral cavity. Recommendations and the rationale for the use of specific equipment (curved or straight blades, cuffed vs uncuffed tubes) are described in Chapter 25. Use of size-appropriate equipment for pediatric airway management is critical to success, even in the most experienced hands. Proper BMV technique is particularly important in pediatric patients because the indication for airway support is most commonly hypoxia

related to a respiratory disorder (ie, RSV bronchiolitis or hypoventilation from seizure). In addition, pediatric patients are subject to more rapid oxyhemoglobin desaturation, so that BMV with cricoid pressure (Sellick maneuver) applied to prevent gastric insufflation is frequently required during the preoxygenation and paralysis phases of rapid sequence intubation. Pediatric BMV requires smaller tidal volumes, higher rates, and size-specific equipment. The pediatric airway is particularly amenable to positive-pressure ventilation, even in the presence of upper airway obstruction (see Chapters 25 and 27).

Tips for Successful BMV Ventilation in Children

To ensure successful BMV in a pediatric patient, the mask seal must be adequate, the airway open, and the rate and volume of ventilation appropriate to the patient's age. Pitfalls in technique include a tendency, in the excitement of the situation, to press the mask portion of the unit downward to obtain a tight seal, resulting in neck flexion and upper airway obstruction. The head should be extended slightly rather than flexed, thereby relieving, rather than producing, obstruction caused by the tongue and the relaxed pharyngeal anatomy (**Fig. 26.1**).

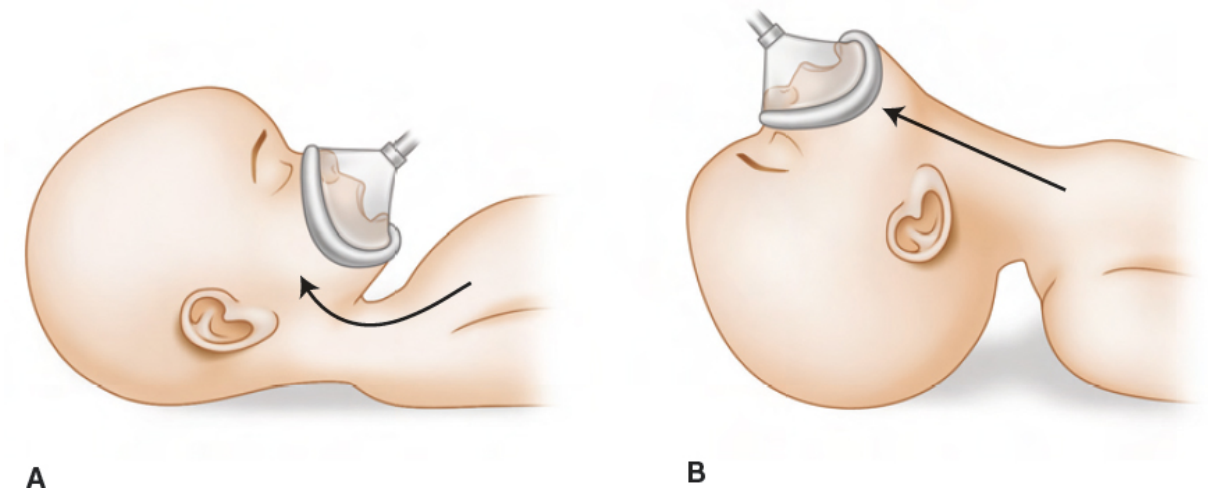

Figure 26.1: A: *Bad* bagging. Fast cadence. B: *Good* bagging. Squeeze, release, release. Part A demonstrates the flexed position causing obstruction, whereas Part B demonstrates extended position that relieves obstruction.

The positioning described in the previous paragraph is usually obtained while applying the one-handed, C-grip technique to the mask. The thumb

and index finger support the mask from the bridge of the nose to the cleft of the chin, avoiding the eyes. The bony prominences of the chin are lifted by the rest of the fingers toward the mask, rather than pressing the mask down, which places the head in mild extension to form the sniffing position. Care is taken to avoid pressure on the airway anteriorly to prevent collapsing and obstructing the pliable trachea.

A two-handed technique can also be used. Whereas this technique is critical for successful rescue mask ventilation of adults, it may be selectively applied in small children. By opening the jaw slightly and pulling it forward, an obstruction may be relieved. The jaw can be moved further forward after opening the mouth slightly ("translating the mandible" forward; see Chapter 12) while using the thenar eminences of the palm to seal the mask on the face. The thenar grip is more effective at creating a uniform seal and minimizing leak around the margin of the mask. Once the mask is applied, a second provider squeezes the bag. If ventilation is not immediately facilitated with these maneuvers, positioning should be reassessed and a nasopharyngeal airway placed to supplement the oropharyngeal airway.

Another technique-related pitfall is a tendency to bag at an excessive rate. The cadence for bagging should permit adequate time for exhalation (repeating the words "squeeze, release, release" is helpful to ensure adequate cadence). Textbooks recommend faster rates for smaller children. From a practical point of view, however, this cadence can be used for all ages. Always place an oral airway in the unconscious child before ventilating with a bag and mask because the pediatric tongue is large relative to the size of the oropharynx and is more prone to obstruct the upper airway.

Tips for Successful Endotracheal Intubation in Children

Preintubation

1. *Position correctly:* Proper patient positioning is key to prevent obstruction and provide optimal alignment of the axes of the airway. Optimal alignment of the laryngeal, pharyngeal, and oral axes in adults usually requires elevation of the occiput to flex the neck on the torso

and extend the head at the atlanto-occipital joint. Because of the larger relative size of the occiput in small children, elevation of the occiput is usually unnecessary, and extension of the head may cause obstruction. Slight anterior displacement of the atlanto-occipital junction is all that is needed (ie, pulling up on the chin to create the sniffing position). In small infants, elevation of the shoulders with a towel may be needed to counteract the effect of the large occiput that causes the head to flex forward on the chest. Once correctly positioned, the external auditory canal should lie just anterior to the shoulders. Whether this position requires support beneath the occiput (older child/adult) or the shoulders (small infant) or no support (small child) (**Fig. 26.2A**) can be determined using this rule of thumb. These are only guidelines, and it should be recognized that each individual patient is different. A quick trial may be required to find the optimal position. **Figure 26.2B** demonstrates the most common position for intubating the small child, the so-called sniffing position, and how this is achieved in a child of this size.

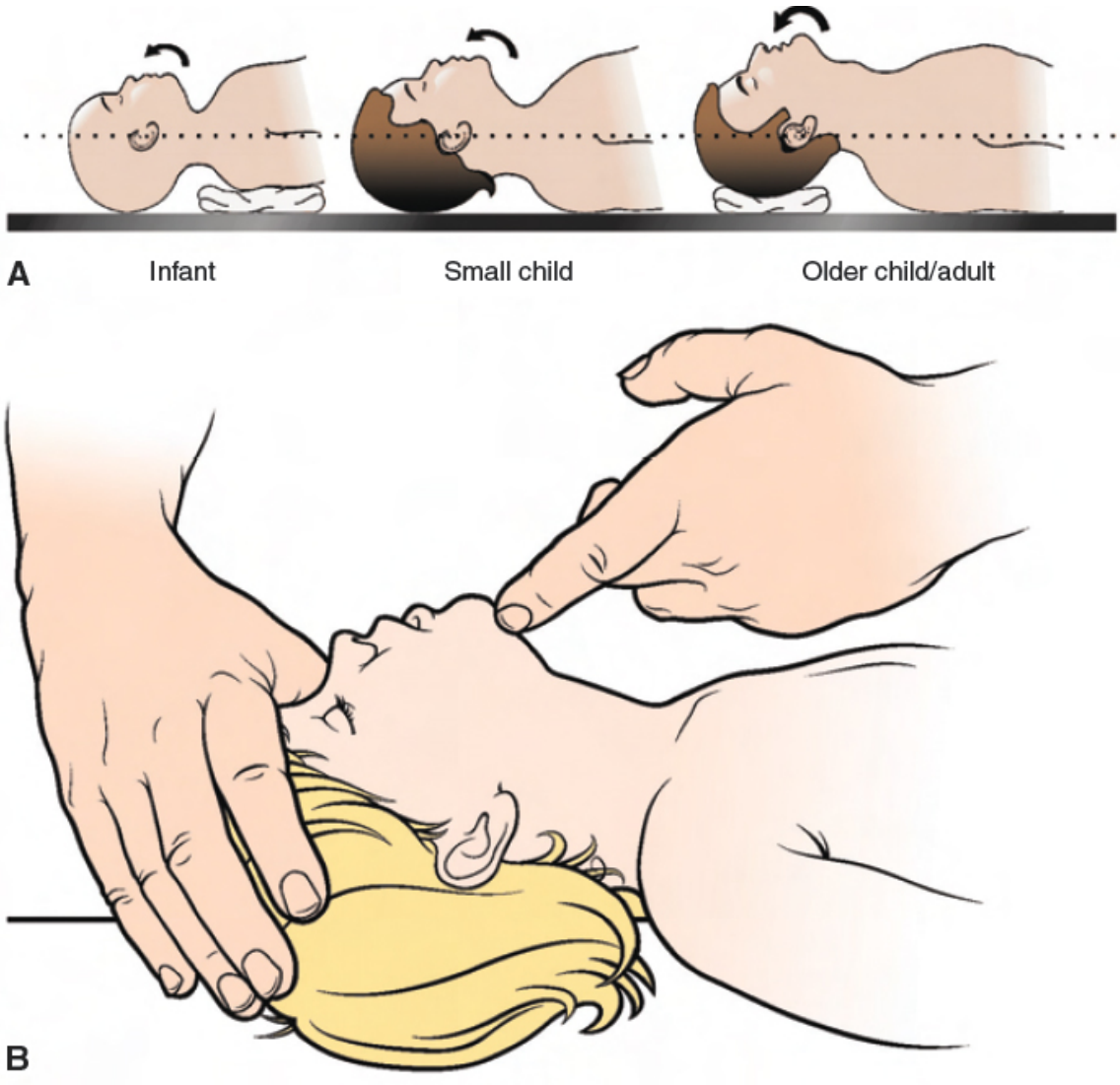

Figure 26.2: A: Clinical determination of optimal airway alignment, using a line passing through the external auditory canal and anterior to the shoulder B: Application of the line to determine optimal position. In this small child, the occiput obviates the need for head support, yet the occiput is not so large as to require support of the shoulders. Note that a line traversing the external auditory canal will pass anterior to the shoulders. With only slight extension of the head on the atlanto-occipital joint, the sniffing position is achieved.

Even with optimal positioning, external manipulation of the airway (eg, backward, upward [cephalad], and rightward pressure maneuver) may increase visualization of the glottis. This may be especially helpful in small children who have superiorly located airways and trauma patients who cannot be optimally aligned.

2. *Mark lip-to-tip distance with tape:* The endotracheal tube (ETT) has centimeter markings along its length. The lip-to-tip distance is the distance from the lip to a point halfway between the vocal cords and the carina (ie, midtrachea), which represents ideal positioning of the ETT in the trachea. Before a pediatric intubation, the ETT should be marked clearly with tape at the appropriate lip-to-tip distance. This will serve as a visual reminder to the intubator as to the correct ETT insertion depth for this patient.
3. *Always select one tube size larger and one tube size smaller than the predicted tube size:* Note that all three tubes are taped at the same predicted lip-to-tip distance. **The lip-to-tip distance is constant for a given patient and does not change if a smaller tube or larger tube is used.** As a rule of thumb, three times the predicted ETT size is used to estimate the lip-to-tip distance; for example, for a 3.5-mm ETT, the lip-to-tip distance would be 10.5 cm. Should a smaller tube, ultimately be used because of a traumatized, narrowed glottic opening, recalculation of the lip-to-tip distance using the smaller diameter would result in an incorrect distance.

Direct Laryngoscopy

1. *Look up not deep:* The pediatric airway lies higher in the neck than the adult airway. When doing direct laryngoscopy, the visual line of sight angle must be adjusted so that the intubator can *look up* to see the glottic opening. Failure to recognize this anatomic peculiarity in children can result in the laryngoscope being “too deep” and bypassing the glottic structures.
2. *Use a stylet:* The pediatric ETT is smaller and more pliable than the larger adult tubes. Therefore, a stylet is recommended for all pediatric intubations.
3. *Enter from the side:* As in the adult, passing the ETT down the center of one’s line of sight obliterates the glottic vestibule. Entering from the side of the mouth with the ETT permits one to always keep the target in view. This maneuver is probably more important in children than in adults because the mouth opening and field of view are smaller in children.

4. *Use the maxilla to stabilize your hand after passing the ETT:* The thumb of the right hand naturally contacts the maxilla during this procedure. It should be stabilized and maintained in that position, holding the tube to prevent movement until it is secured.
5. *Consider using a bougie or other tube introducer:* A bougie may be a helpful adjunct, especially if it is a difficult airway or you have a less-than-ideal view. With gentle insertion of a bougie, you can confirm position by feeling tracheal rings, and then advance your ETT over the bougie.

Postintubation

Inadvertent extubation is a frequent, but entirely avoidable, complication. ETTs must be secured at the lip to negate head movement, thereby avoiding tube movement. Flexion of the neck causes the tube to move further down into the airway, whereas neck extension causes the tube to move up and out of the trachea. This effect is most marked in the younger child with a proportionally larger occiput. Securing the ETT at the lip is traditionally done by taping the tube to the maxilla to prevent the tube from slipping in or out. Adequate securing of the ETT with tape requires experience. An alternative to taping is the application of various commercial ETT holder devices.

Application of a cervical collar prevents the flexion and extension movements of the neck and maintains ETT position in the trachea, preventing inadvertent extubation.

BMV and Cricoid Pressure

The application of cricoid pressure has fallen out of favor as a method to prevent aspiration during emergency airway management, but cricoid pressure may help prevent gastric insufflation with BMV, even with ventilation pressures >40 cm H_2O. This is especially important in infants, in whom gastric distention may compromise ventilation and increase the risk of aspiration.

Positive-Pressure Relief Valves ("Pop-Off" Valves)

A pop-off valve is designed to prevent the delivery of excessive pressure to the lower airway and limit the risk of barotrauma. These valves are present

on most infant and pediatric resuscitation bags. The relief valve opens at a preset peak airway pressure (varying from 20- to 45-cm water pressure, although most are set at 40 cm), limiting the peak pressure that can be delivered to the lungs. However, in the face of upper airway obstruction, increased airway resistance, or decreased pulmonary compliance, higher pressures may be required to adequately ventilate. In situations such as these, the operator should disable the valve.

In addition to the pop-off valve, many manufacturers incorporate manometers into the unit so that one can monitor peak airway pressures as they perform BMV. A leak at the site of the manometer port may interfere with one's ability to achieve airway pressures sufficient to effect adequate gas exchange.

Even though troubleshooting inadequate BMV starts with evaluating the adequacy of mask seal and assessing airway patency, the performance of a "leak test" immediately before beginning BMV will establish the status of the pop-off valve and test for a leak at the manometer site (or other parts of the unit). The leak test is performed by removing the mask from the bag, occluding the mask port with the palm of one hand, and squeezing the bag with the other hand. If the bag remains tight, no escape of gas, or "leak," has occurred. If the bag does not remain tight, gas is escaping from the system somewhere, most commonly from the pop-off valve or the manometer port, although other causes of the leak may be present. The pressure leakage from an open manometer port occurs immediately on compressing the bag as opposed to the open pop-off valve, which vents only once the preset pressure is exceeded. The amount of volume lost will vary, depending on the size of the leak. This test is also useful for screening adult bags for malfunctions and leaks. After a negative test (ie, the bag remains tight with squeezing), the port occluding palm hand should be released, and the bag squeezed to confirm that gas escapes properly from the inspiratory limb of the bag.

Laryngeal Mask Airways

The laryngeal mask airway (LMA) is a safe and effective airway management device for children undergoing general anesthesia and is considered a rescue option in the event of a failed airway in children and

infants. Placement of the LMA in children is a relatively easily learned skill, particularly if the correct size is chosen. The LMA has also been used successfully in difficult pediatric airways and should be considered as an alternative device for emergency airway management in these patients (eg, Pierre Robin Sequence). As in the adult, difficult pediatric intubations have also been facilitated using the LMA in combination with such devices as a flexible bronchoscope.

The LMA has a few important associated complications, which are especially prevalent in smaller infants, including partial airway obstruction by the epiglottis, loss of adequate seal with patient movement, and air leakage with positive-pressure ventilation. To avoid obstruction by the epiglottis in these younger children and infants, some authors have suggested a rotational placement technique in which the mask is inserted through the oral cavity “upside down” and then rotated 180° as it is advanced into the hypopharynx. The LMA is contraindicated in the pediatric patient or adult with intact protective airway reflexes and is therefore not suitable for awake airway management. LMA use is also contraindicated if foreign body aspiration is present or suspected because it may aggravate an already desperate situation. Furthermore, the LMA is unlikely to provide adequate ventilation and oxygenation because the obstruction is distal to the device. The LMA comes in multiple sizes to accommodate children from neonate to adolescent. The i-gel, a noninflatable LMA-style extraglottic device, is available in a variety of pediatric sizes and serves a similar purpose.

Percutaneous Needle Cricothyrotomy or “Needle Cric”

Although virtually every textbook chapter, article, or lecture on pediatric airway management refers to the technique of needle cricothyrotomy as the recommended last-resort rescue procedure, there is little literature to support its use and safety. Few of the “experts” who write about needle cricothyrotomy have experience performing the procedure on live humans, yet any clinician who manages pediatric emergencies as part of his or her practice must be familiar with the procedure and its indications and must have the appropriate equipment readily accessible in the emergency department.

Needle cricothyrotomy is indicated as a lifesaving, last-resort procedure in children younger than 10 years who present with or progress to the “can’t intubate, can’t oxygenate” scenario and whose obstruction is proximal (cephalad) to the vocal cords. The classic indication is epiglottitis, where BMV and intubation are judged to have failed (although true failure of BMV is rare in epiglottitis, and failure is more often caused by a failure of technique than by a truly insurmountable obstruction). Other indications include facial trauma, angioedema, and other conditions that preclude access to the glottic opening from above. Needle cricothyrotomy is rarely helpful in patients who have aspirated a foreign body that cannot be visualized by direct laryngoscopy because these foreign bodies are usually in the lower airway. It would also be of questionable value in the patient with croup because the obstruction is subglottic. In these patients, the obstruction is more likely to be bypassed by an ETT introduced orally into the trachea with a stylet than blindly by needle cricothyrotomy.

Various commercially available needles are also available for percutaneous needle cricothyrotomy (**Table 26.1**). The simplest equipment, appropriate for use in infants, consists of the following:

- 14G over-the-needle catheter
- 3.0-mm ETT adapter coupled with an IV extension set (These can be obtained commercially or constructed by cutting off 6 in. of distal IV tubing and inserting a 2.5-m adapter into the opening; see **Fig. 26.3**.)

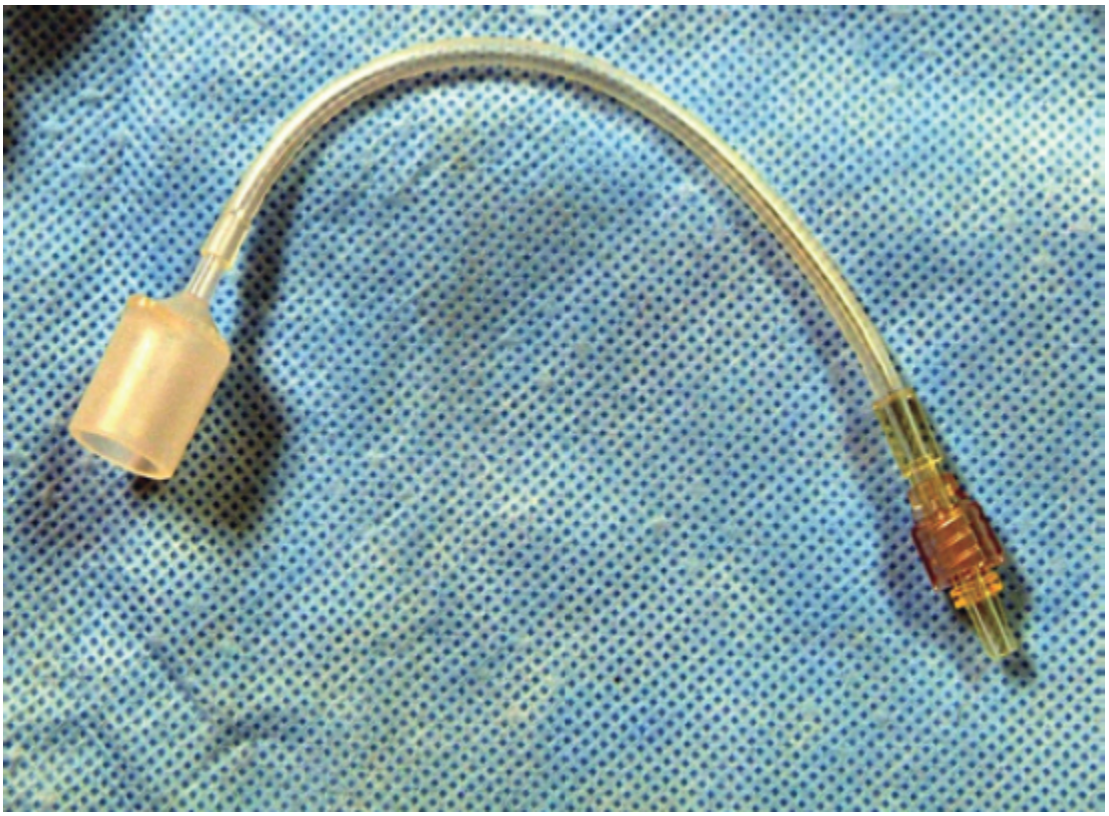

Figure 26.3: Components of a needle cric extension set. This extension set is constructed by cutting off the terminal 6 in. of standard IV tubing and inserting a 2.5-mm ETT adapter. The bag-mask ventilation (BVM) is attached to the adapter at the proximal opening, and the distal end is inserted into the catheter that has been introduced into the trachea. This setup allows more freedom of movement during BMV, with less concern for "kinking" or obstructing the catheter—a complication observed in animal studies when the bag was connected directly to the 3.0 ETT adapter.

- 3- or 5-mL syringe

TABLE 26.1 Recommended Commercial Catheters

These catheters are available commercially and can be used as an option:

Jet ventilation catheter (Ravussin). Sizes 13G and 14G, not the 16G catheter. Although listed as jet ventilation catheters, we recommend them only for use with BMV.

6F cook emergency transtracheal airway catheters. They are available in two sizes, 5 and 7.5 cm. We only recommend the 5-cm catheter.

It is a good practice to preassemble the kit, place it in a clear bag, seal the bag, and tape it in an accessible place in the resuscitation area.

Procedure

Place the child in the supine position with the head extended and a towel under the shoulders. This forces the trachea anteriorly such that it is easily palpable and can be stabilized with two fingers of one hand. The key to success is strict immobilization of the trachea throughout the procedure. The following statement appears in many textbooks describing this procedure: “Carefully palpate the cricothyroid membrane.” In reality, it is difficult to do this in an infant and is not essential. Indeed, in smaller children, it may be impossible to precisely locate the cricothyroid membrane, so the proximal trachea is utilized for access [hence the name percutaneous needle tracheostomy (PNT) vs “needle cric”]. The priority is an airway and provision of oxygen. Complications from inserting the catheter elsewhere into the trachea besides the cricothyroid membrane are addressed later. Consider the trachea as one would a large vein, and cannulate it with the catheter-over-needle device directed caudally at a 30° angle. Aspirate air to ensure tracheal entry, and then slide the catheter gently forward while retracting the needle. Attach the 3.0-mm ETT adapter to the hub of the catheter and commence bag ventilation. The provider will note exaggerated resistance to bagging. This is normal and is related to the small diameter of the catheter and airflow turbulence. It is not generally the result of a misplaced catheter or poor lung compliance secondary to pneumothorax. It is helpful to practice BMV through a catheter to experience the feel of this increased resistance. The operator must allow for full expiration through the patient’s glottis and not through the catheter in order to prevent breath-stacking and barotrauma. This can be accomplished by watching for the chest to fall after inspiration.

The required pressures are well above the limits of the pop-off valve; therefore, it must be disabled in order to permit gas flow through the catheter. Jet ventilation has also been advocated in children; indeed, the terms “needle cric” and jet ventilation are frequently referred to in the literature as the procedure of choice. The reality is that the pressures generated by the classic jet ventilator are extremely high and both unnecessary and potentially dangerous as an adjunct for use with this procedure in children.

Although needle ventilation in the setting of “complete” upper airway obstruction is relatively contraindicated (owing to concern about barotrauma in the absence of exhalation), in reality “complete” obstruction

is extremely rare in children. Referring to the explanation of the usual mechanism of obstruction (Chapter 27), one can see that the terminal events are respiratory arrest from closure of the airway secondary to negative patient breaths, which result in airway collapse. Once arrest occurs, negative patient breaths cease, and the airway relaxes and expands slightly. Also, the negative patient breaths are replaced with positive-pressure ventilation, which may further expand the narrowed airway. Thus, egress of gas during ventilation is typically not an issue.

TECHNIQUES USED IN ADOLESCENTS AND ADULTS

Blind Nasotracheal Intubation

Nasotracheal intubation in children is not a viable rescue technique owing to the sharp angle of the nasopharynx and pharyngotracheal axis in children, which makes successful nasotracheal intubation exceedingly difficult. Additionally, children are at increased risk for hemorrhage because of the preponderance of highly vascular and delicate adenoidal tissue. The direct visualization technique is, however, commonly used in small infants and children for chronic ventilator management in the intensive care unit setting. Using direct visualization with a laryngoscope once the ETT has passed into the oro- and hypopharynx, tracheal placement is aided with Magill forceps. However, this technique is not helpful in emergency airway management. In general, blind nasotracheal intubation is not recommended for patients younger than 10 years.

King LTS-D

The King LTS-D airway is an extraglottic device that has available pediatric sizes (down to <5 kg body weight). Advantage of the King LTS-D is ease of use because it is designed to be placed blindly and has a single BMV connection and balloon insufflation port.

Surgical Cricothyrotomy

The cricothyroid membrane in small infants and children is minimally developed (**Fig. 26.4**). Surgical cricothyrotomy should not be attempted in children younger than 10 years. In children younger than 10 years, PNT

with BMV is recommended. Note that our recommended limit of 10 years of age is not meant to be a rigid guideline. Various ages have been recommended as a cutoff for performing one procedure versus the other. For cricothyrotomy, it is really an issue of size. If the size of the patient's airway and cricothyroid membrane would permit performing a surgical cricothyrotomy, that is, easily identifiable landmarks are present, then, regardless of age, it can be done. If not, then the needle technique should be performed. Cricothyrotomy using a commercially available kit (Pedia-Trake) has not been shown to be successful or even safe. **Box 26.1** summarizes recommendations for invasive airway procedures in children.

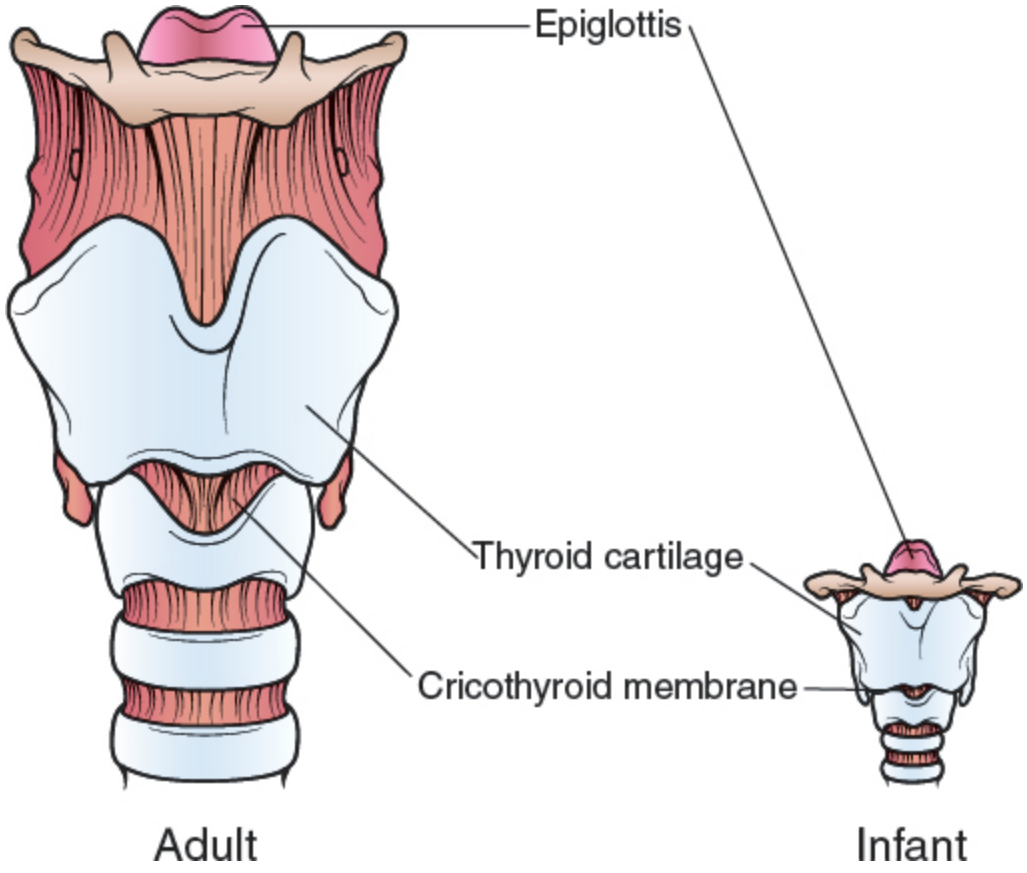

Figure 26.4: Cricothyroid membrane. Comparative size of the adult (left) versus pediatric (right) cricothyroid membrane. Note that not only is the larynx smaller but also the actual membrane is proportionately smaller in comparison, involving one-fourth to one-third the anterior tracheal circumference versus two-thirds to three-fourths in the adult. This pediatric drawing is that of a toddler, which accommodates a 4.5-mm ETT.

BOX 26.1 Summary Recommendations for Invasive Airway Procedures in Children

5 years
Percutaneous needle tracheostomy and bag ventilation

5-10 years
Percutaneous needle tracheostomy and bag ventilation[a]
Percutaneous Seldinger technique and bag ventilation[b]

>10 years
Operator preference for various commercial kits
Surgical cricothyrotomy

[a]*There is less evidence to support this recommendation in this age group; however, it may be the only available option and should be converted to a more definitive airway.*

[b]*If the size of the cricothyroid membrane is sufficient.*

EVIDENCE

Does a needle cricothyrotomy with BMV in children provide sufficient oxygenation and ventilation to avoid hypoxia and hypercarbia?

The evidence surrounding pediatric needle cricothyrotomy is based on an animal study by Cote et al.[1] using a 30-kg dog model. Cote was able to demonstrate that dogs approximate in size to a 9- to 10-year-old child could be oxygenated through a 12G catheter and 3.0 ETT adapter with a bag for at least 1 hour (the study duration). Elevation in $PaCO_2$ levels was noted but were not believed to be significant because children normally tolerate mild degrees of hypercarbia well.[1]

One adult retrospective study reported that 48 patients were successfully oxygenated and ventilated using transtracheal ventilation through a 13G intratracheal catheter for up to 360 minutes. Transtracheal jet ventilation (TTJV) was used primarily in 47 of these patients, although 6 patients did receive conventional bagging measures until TTJV circuits could be initiated. During manual transtracheal ventilation, each patient demonstrated increases in $PaCO_2$ on blood gases but maintained PaO_2 values >100 mm Hg.[2]

Should the LMA be considered as both a rescue device and an alternative airway in the management of difficult emergency pediatric airways?

Most of the literature regarding the use of LMAs in children has been compiled from the anesthesia experience in the operating room. Therefore, little information is available for the use of the LMA in the acute emergency setting. However, an observational study by Lopez-Gil et al.[3,4] has demonstrated that the skill for placement of the LMA could be rapidly learned by anesthesia residents with a low complication rate. Published case reports have demonstrated success of the LMA in the pediatric patient with difficult airways, including isolated severe retrognathia, Dandy-Walker syndrome, and Pierre Robin Sequence.[5,6]

At least one prospective study reports a higher incidence of airway obstruction, higher ventilatory pressures, larger inspiratory leaks, and more complications in smaller children (those weighing <10 kg) with LMA use than in the older child. These authors recommend that the risk–benefit should be carefully weighed in younger children before using the LMA with paralysis and positive-pressure ventilation. Importantly, the success rate for placement of the LMA in this study that was performed in elective cases undergoing prolonged ventilation was high, at 98%.[7] Although airway managers should be aware of these potential complications, this study is not generalizable to the emergency setting and should not deter providers from implementing this as a *rescue device* in infants or young children with failed airways or as a planned approach to an infant or young child with an identified difficult airway. In the failed airway situation, the LMA may be a lifesaving bridge, providing effective oxygenation and ventilation until a definitive airway can be secured.

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CHAPTER 27

The Difficult Pediatric Airway

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Robert C. Luten

INTRODUCTION

Age-related anatomic and physiologic differences in the normal infant or small child can make airway management challenging. However, these differences can be anticipated and addressed in most pediatric patients, as discussed in Chapter 25. The *difficult* pediatric airway, as in adults, is defined by historical or physical examination attributes that predict challenges with mask ventilation, laryngoscopy, or intubation. In the pediatric population, most cases of anatomically difficult airways result either from acute insults that modify normal airway structures or from known congenital abnormalities. Difficulty related to unpredictable anatomic abnormalities revealed only after unsuccessful attempts at airway management, resulting in a *failed* pediatric airway, is rare in children.

The approach to the emergent difficult airway in the adult patient is described in Chapter 2, which should be read before this chapter. The same concepts of anticipation and planning are also applicable in children. The use of rapid, easy-to-remember, and sensitive tools to identify patients with potential difficulty is paramount. Children differ from adults, however, with regard to which predictors of difficulty are most common (see **Table 27.1**). For example, age-dependent features (eg, beards and age >55 years) and progressive disease processes (eg, cervical rheumatoid arthritis) are not applicable in children. However, using LEMON to prompt recognition of abnormal facial features and assessing for signs of obstructive airway disease will be of high yield (see **Table 27.2**). Most children with difficult airways will present with recognizable disease processes or with previously identified congenital abnormalities associated with airway difficulty. This chapter will focus on common etiologies of difficult pediatric airways and offer management strategies. **Table 27.3** offers a general approach to the management of both normal and difficult pediatric airways.

TABLE 27.1 A Sample Comparison of Pediatric and Adult Risk Factors

A. Risk factors for adult difficult airway usually not present in infants and young children:

1. Obesity
2. Decreased neck mobility (excluding immobilization following trauma)
3. Teeth abnormalities
4. Temporomandibular joint problems
5. Beards

B. Risk factors for pediatric difficult airway not present in adults:

1. Small airway caliber susceptible to obstruction from edema or infection
2. Discomfort secondary to dealing with age- and size-related variables
3. Discomfort secondary to infrequency of patient encounters

TABLE 27.2 Key Features in Applying the LEMON Assessment in Children	
Look	• Gestalt is the most important predictor of airway difficulty in children • Presence of dysmorphic features is associated with abnormal airway anatomy and may predict difficulty • Small mouth, large tongue, recessed chin, and major facial trauma are usually immediately apparent
Evaluate (3:3:2)	• Has not been tested in children • May be difficult to perform in an uncooperative child or infant with a “pudgy” neck • Gross assessment of mouth opening, jaw size, and larynx position may be utilized instead • If 3:3:2 assessment is performed, use the child’s, not the provider’s fingers
Mallampati	• Cooperation may be an issue • Mixed data in children (see “Evidence” section)
Obstruction Obesity	• Airway obstruction is a relatively frequent indication for airway management in children • Second to the gestalt *Look*, assessing for obstruction is perhaps the most fruitful step in identifying difficult airways in children • A focused, disease-specific history and physical examination (voice change, drooling, stridor, and retractions) can accurately identify children with acute or chronic upper airway obstructive pathology • Obesity is a growing epidemic in children, although the impact on the pediatric airway is less significant than in adults
Neck	• Limited positioning in immobilized pediatric trauma patients is similar to that in adults • Intrinsic cervical spine immobility from congenital abnormalities is very rare, and acquired conditions (eg, ankylosing spondylitis and cervical rheumatoid arthritis) are essentially nonexistent in young children

TABLE 27.3 General Approach to the Pediatric Airway—Normal Versus Difficult

Anticipated "Normal" Airway	
Prerespiratory Failure	• Non-rebreather high-flow nasal cannula • Noninvasive ventilation
Respiratory Failure (Immediate and/or Transient)	• Bag-mask ventilation[a]
Respiratory Failure	• Rapid sequence intubation • Direct or video laryngoscopy
Anticipated/Unexpected "Difficult" Airway	
Cannot Intubate, Can Ventilate[b]	• Extraglottic device • Video laryngoscopy
Cannot Intubate, Cannot Ventilate	• "Surgical" airway (needle, Seldinger or open)
Concern for Possible Airway Difficulty	
• Predicting whether a given patient is likely to have a normal or difficult airway is a clinical decision that guides the type of equipment that will need to be utilized to secure the airway. • When the clinical assessment is uncertain, the clinician may choose to perform an "awake sedated look." • Ketamine 2 mg/kg is administered, which produces a state of dissociation while maintaining respiratory effort that allows the clinician to insert a laryngoscope and assess whether glottic opening visualization is feasible or not, thus guiding subsequent airway interventions.	

[a]*May be useful as temporizing measure with airway obstruction.*
[b]*May include dysmorphic features.*

COMMON CAUSES OF DIFFICULT AIRWAYS IN CHILDREN

Causes of difficult airways in children can be categorized into four groups:

1. Acute infectious causes
2. Acute noninfectious causes
3. Congenital anomalies
4. No known abnormality, with unexpected difficulty

Difficult Airways Secondary to Acute Infectious Causes

Examples of acute infectious processes that alter an otherwise normal anatomy include the following:

- Epiglottitis

- Croup
- Bacterial tracheitis
- Retropharyngeal abscess
- Ludwig angina

Epiglottitis is the classic paradigm for an acute infectious process resulting in a difficult airway. Although disease incidence has declined dramatically since the introduction of the *Haemophilus influenzae* type b (Hib) vaccine, cases continue to be reported secondary to vaccine failures or alternative bacterial etiologies, most commonly gram-positive cocci. Progressive edema and swelling of the epiglottis and surrounding structures can quickly lead to proximal airway obstruction. Because the diagnosis is uncommon and the management is challenging, hospitals should utilize protocols that allow emergency physicians, anesthesiologists, and surgical personnel to work quickly and collaboratively to construct an airway plan for any child with a concerning presentation. Agitating a child with epiglottitis can increase turbulent airflow and aggravate airway obstruction. Ideally, airway evaluation and intervention should occur in the controlled setting of an operating room where equipment and staff are available for rigid bronchoscopy and age-appropriate surgical airway management as needed. However, if a child deteriorates, attempts at bag-mask ventilation (BMV), direct laryngoscopy, and endotracheal intubation may be necessary in the emergency department (ED). If these efforts are unsuccessful, needle cricothyrotomy (see Chapter 26) can be lifesaving. A surgical airway will bypass the proximal obstruction and allow oxygenation and some degree of ventilation through the patent trachea.

Croup is a common reason for children to present to the ED with airway compromise, although the need for advanced airway management is rare. Although commonly grouped with epiglottitis, croup is a clinically distinct entity (see **Table 27.4**). Respiratory distress is common, because subglottic airway narrowing can have a profound effect on airway resistance on the smaller-diameter trachea in children (see **Table 27.5**). However, croup patients are rarely toxic appearing. Patients with croup generally respond well to nebulized epinephrine and steroids, and intubation is rarely required. If patients present in extremis or medical therapy fails, bagging may be difficult secondary to increased airway resistance; however, visualization during laryngoscopy is typically not affected.

TABLE 27.4 Management of the "Most-Feared" Pediatric Airway Problems

Disease	Pathology and Deterioration	Approach	FB Removal Maneuvers	BMV Two-Person Techniques	Intubation	Needle Cricothyrotomy
Epiglottitis	Rapidly progressing disease process affecting the supraglottic structures (epiglottis and aryepiglottic	Stable → observe → OR for definitive airway Decompensation: BMV → intubation	Not indicated	Effective in *most* patients who deteriorate Technique: A two-handed	Usually successful. Use tube size 1 mm smaller. Use stylet. Suction, visualize,	The paradigm indication for needle cricothyrotomy *if* BMV and intubation are unsuccessful

	folds). Patients are usually ill appearing, although they may be in minimal distress. Decompensation can occur:	Failed Airway: needle cricothyroidotomy		seal, with another rescuer providing sufficient pressure to overcome the obstruction	press on chest, and look for bubble	
	1. When a patient is stimulated or manipulated, leading to dynamic airway obstruction					
	2. As a result of progressive deterioration over time secondary to fatigue, although the respiratory arrest may occur precipitously					
Croup	Slowly progressive (hours to days) disease process affecting the subglottic trachea, causing dynamic inspiratory augmented obstruction. Deterioration is usually progressive rather than sudden and related to respiratory muscle fatigue, although, as in the case of epiglottis, the arrest may also occur precipitously	Stridor at rest: racemic epi and steroids Persistent distress: ICU Decompensation: BMV → Intubation	Not indicated	Effective. Positive pressure overcomes obstruction by acting as a stent. May require high pressures	Proximal airway normal; therefore, should not be problematic. Consider ETT one size smaller and use stylet	Not indicated because obstruction is distal to cricothyroid membrane
FB aspiration (see	Patients with aspirated FBs have the potential for	Stable: observe → transfer for removal Decompensation:	Indicated if *appropriate* (ie, patient	Should not be used before attempts to	Last resort in an effort to push FB distally into	Usually not indicated because FB will be distal to the

Chapter 28)	decompensation secondary to acute airway obstruction. The level of obstruction may vary from the hypopharynx, above or below the glottis, to the mainstem bronchus	FB removal maneuvers → Direct visualization and removal with Magill forceps → Intubation to force FB distally into mainstem bronchus	completely obstructs)	remove FB. May be obviated by intubation	mainstem bronchus	obstruction if other efforts have failed.

BMV, bag-mask ventilation; epi, epinephrine; ETT, endotracheal tube; FB, foreign body; ICU, intensive care unit; OR, operating room.

TABLE 27.5 Effect of 1-mm Edema on Airway Resistance

	Change in Cross-sectional Area	Change in Resistance
Infant	44% decrease	200% increase
Adult	25% decrease	40% increase

These figures reflect the quietly breathing infant or adult. If the child cries, the work of breathing is increased 32-fold. This underscores the principle of maintaining children in a quiet, nonthreatening, and comfortable environment during evaluation and in preparation for management.

If a child with croup is ill enough to require intubation, a smaller endotracheal tube (ETT) should be used because the edematous subglottis will be narrowed and may not accommodate age- or length-predicted ETT size. It is important to remember, however, that the ETT insertion distance (ie, lip-to-tip distance) is *not* affected despite the use of a smaller-sized tube. Therefore, although length-based references such as a Broselow-Luten tape to determine this distance will remain accurate, formulaic calculation based on the tube diameter (ie, 3 times the ETT size) should be based on the *predicted* age-appropriate ETT size, not the downsized tube.

Bacterial tracheitis has become a leading cause of respiratory failure from acute upper airway infections. Affected children tend to be older than patients with croup and are likely to be ill appearing. As in croup, inflammation in tracheitis is subglottic, and the approach to airway management is therefore similar. Again, visualization is rarely compromised; however, a smaller ETT size should be used. Using a cuffed ETT has two advantages. First, it allows for adjustments in cuff inflation volume to accommodate any air leak if the airway is less edematous than anticipated. Second, it allows for higher airway pressures during ventilation, if obstructive plaques in the distal airway were to increase airway resistance. It is important to recognize that the presence of such thick purulent secretions within the trachea will require vigilant monitoring for tube obstruction.

Retropharyngeal abscesses or other deep neck infections rarely presents with airway compromise, although they are frequently included in the differential diagnosis of acute life-threatening upper airway obstruction. These patients most commonly present with odynophagia and neck stiffness. Lateral neck films reveal thickening if the infection is truly retropharyngeal, although the prevertebral space may appear normal for

parapharyngeal or lateral collections. Most of these patients respond to antibiotics, although in some cases drainage in the operating room is required. Rarely is it necessary to actively manage the airway in the ED. If the obstruction is large enough to require emergent airway intervention, it is important to remember that placement of an extraglottic device (EGD) may not be feasible and that alternative backup approaches should be considered.

Ludwig angina is an exceedingly rare pediatric diagnosis and is unlikely to require emergency airway management in the ED. If encountered, difficulty with displacement of the tongue into the inflamed submandibular space should be anticipated, and approaches other than direct laryngoscopy should be readily available.

Difficult Airways Secondary to Noninfectious Processes

- Foreign body
- Burns
- Anaphylaxis and angioedema
- Trauma

Foreign body aspiration is perhaps the most-feared pediatric airway problem. Therefore, the approach to the child with airway compromise from foreign body aspiration has earned a full discussion in Chapter 28.

Patients with upper airway burns or inhalational injuries can be identified by soot in the mouth, carbonaceous sputum, singed nasal hair, or facial burns. Caustic ingestions may show facial or oropharyngeal mucosal injury. If upper airway edema has already occurred, patients may have drooling, hoarseness, or frank stridor. In contrast to processes like croup that commonly improve with medical therapy, patients with significant mucosal injury or edema predictably worsen over time. Therefore, intubation should occur as early as possible because progressive edema will make visualization and tube passage dramatically more difficult over time (see **Table 27.6**). Succinylcholine may be used during rapid sequence intubation (RSI) because the risk of hyperkalemia from burns begins after 3 days. Cuffed ETTs are recommended to accommodate the changes in airway edema over the natural course of recovery. EGDs may not pass easily and may therefore be less reliable as a rescue approach, so surgical airway equipment should be readily available.

TABLE 27.6 Timing of Intervention According to Anticipated Clinical Course

Expectant intervention group
Intervene only if deterioration occurs:
1. Subspecialty multidisciplinary team required for definitive management: a. Foreign body b. Epiglottitis
2. Subspecialty assistance should be assembled if deterioration appears likely:

a. Para-airway diagnoses (eg, retropharyngeal or peritonsillar abscess); usually stable on presentation, and deterioration is uncommon
Early intervention group
1. Intervene early (proactively):
a. Airway compromise unlikely to respond to medical interventions b. Burns c. Trauma
2. Early intervention if there is not rapid response to medical therapies a. Anaphylaxis (usually responds to medical treatment); anaphylactoid-like reactions, eg, angioedema (less reliable response to treatment)

Anaphylaxis and angioedema also cause progressive edema in the tongue, supraglottic structures, and the larynx. The goal is to aggressively maximize medical therapy to limit progression. However, patients with compromised airways secondary to anaphylactic or anaphylactoid reactions (eg, angioedema) who do not rapidly respond to medical treatment require early intervention. As with inhalation injuries, a backup airway management plan should be immediately available.

Trauma poses unique challenges in pediatric airway management. The risk of cervical spine injury requires maintenance of immobilization, which affects the ability to position the patient for optimal visualization and intubation. In addition, facial trauma can impede an effective mask seal, limit mouth opening, or result in blood or secretions in the oropharynx, making visualization difficult. Avulsed teeth, blood, vomitus, or other foreign material can obstruct the airway, whereas an expanding hematoma or displaced bony injuries can impede direct laryngoscopy. Finally, primary neck trauma can distort anatomy or injure the larynx and trachea and risk complete airway compromise during intervention. Despite these challenges, most pediatric trauma patients who require airway intervention will be managed with RSI. Video laryngoscopy (VL), when available, is increasingly being used to improve visualization that may otherwise be compromised by cervical immobilization. Hyperangulated blades will improve visualization over direct laryngoscopy in patients maintained in neutral cervical spine position. Significant trauma may limit the utility of an EGD. Therefore, simultaneous preparation for a surgical airway should be performed as a backup airway plan.

Difficult Airways Secondary to Congenital Anomalies

Patients with difficult airways secondary to congenital anomalies receive disproportionate attention in discussions of difficult airways in pediatrics. However, they are encountered much less frequently than the conditions described earlier. The literature concerning these patients usually describes elective situations, managed by experienced pediatric anesthesiology subspecialists in well-equipped operating rooms performed under

controlled conditions. This information may not translate well to pediatric airway management in the ED setting.

Often, patients with congenital anomalies presenting to the ED require intubation for reasons unrelated to their difficult airway (eg, a child with Pierre Robin syndrome with respiratory failure secondary to bronchiolitis). The best approach for these patients, time permitting, is to obtain expert subspecialty assistance as early as possible and, as with all patients, to aggressively manage the medical condition or utilize noninvasive ventilation to try to obviate the need for endotracheal intubation.

There are a range of anatomic abnormalities and named syndromes that predict difficulty with pediatric airway management. It is impractical and unnecessary to commit all to memory. Instead, common findings can be categorized into four groups, which can be identified using the LEMON assessment (see Table 27.2). These include a small chin (micrognathic mandible), a large tongue, a small or limited-opening mouth, and a neck that is either short or immobile.

The micrognathic mandible is the most common anatomic feature in children that renders intubation difficult. The small mandible reduces the available space into which the tongue and submandibular tissue must be compressed with the laryngoscope blade to visualize the glottic opening (see **Fig. 27.1**). A significantly recessed (or micrognathic) mandible can be recognized by drawing a line that touches the forehead and maxilla and continues inferiorly (**Fig. 27.2**). In a patient with grossly normal anatomy, the line also touches the tip of the chin. In the patient with micrognathia, a gap between the line and the tip of the chin is observed. A relatively large tongue can have a similar effect, with limited room for displacement given its mass and resultant obstruction of the direct view of the glottis.

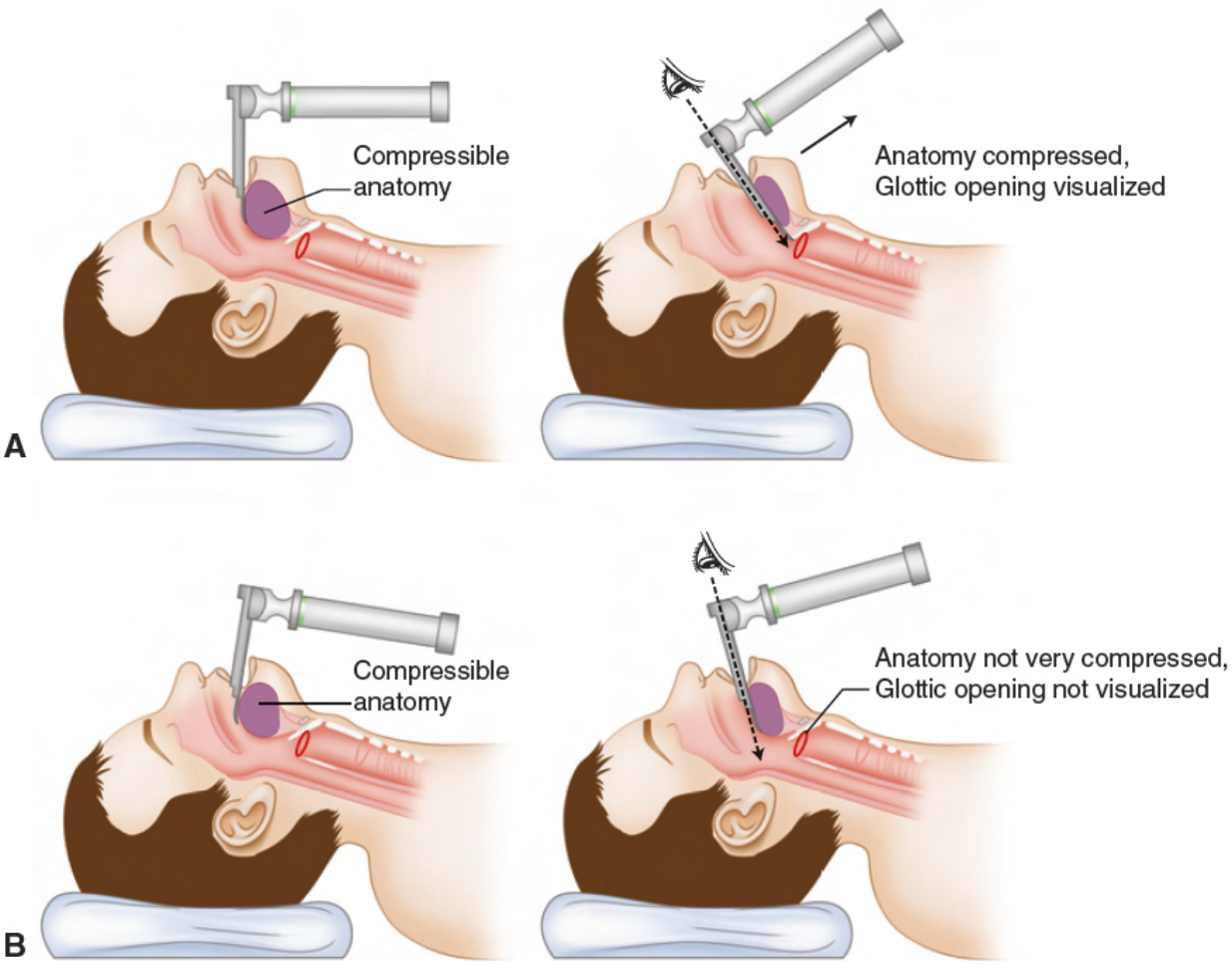

Figure 27.1: A: A normal-sized mandible provides room for the tongue and associated tissue to be compressed into the mandibular space by the laryngoscope blade, allowing visualization of the glottic opening. **B:** A small mandible cannot easily accommodate the tongue, which therefore remains in the line of sight of the laryngoscopist.

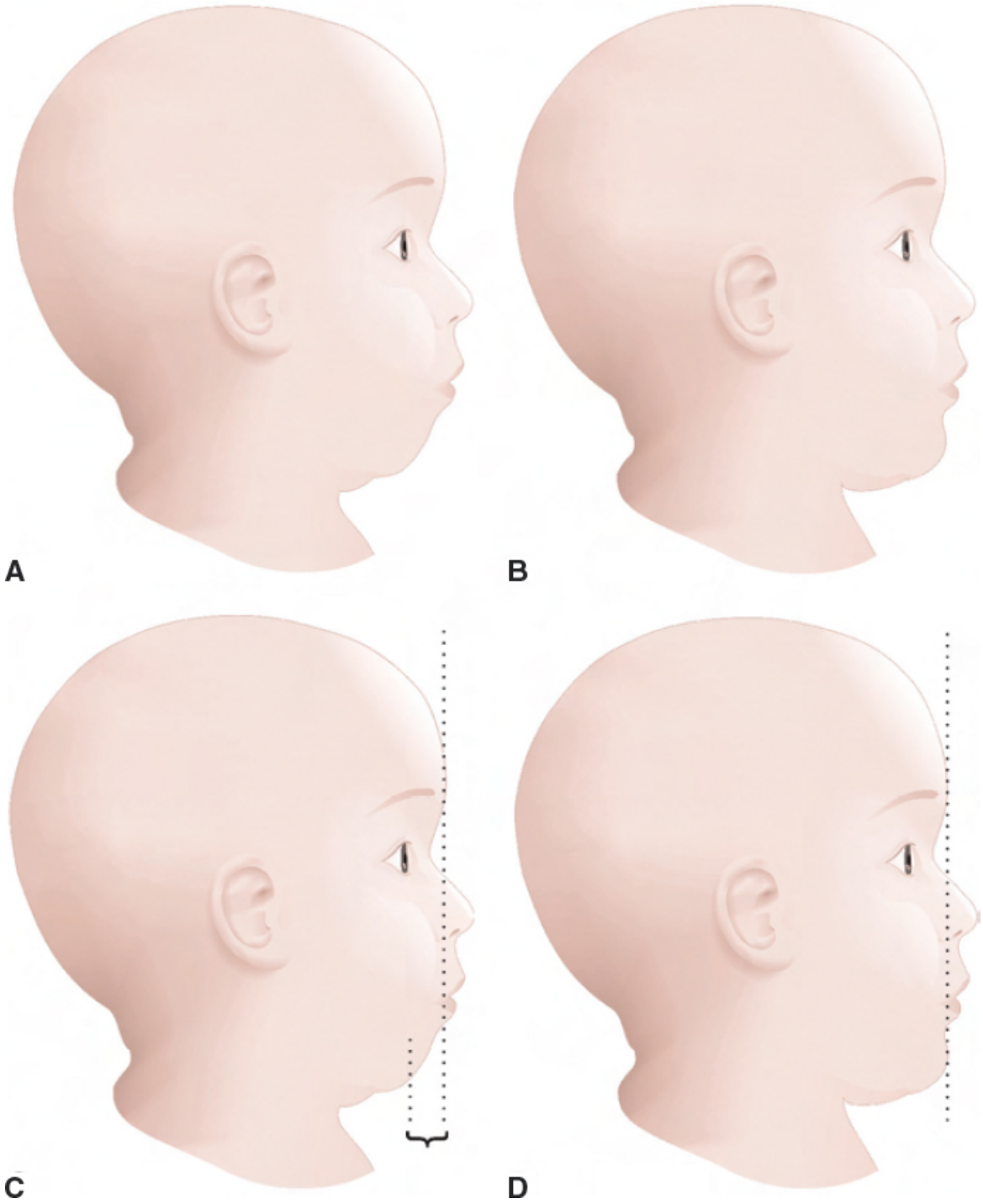

Figure 27.2: It may not always be obvious that a given patient possesses a difficult airway. Micrognathia (A) may not be readily apparent unless compared to a normal child. **B:** In the normal patient, a line drawn from the forehead **(C)**, touching the anterior maxilla, will also touch the chin. D: Failure to do so indicates a degree of micrognathia.

Similarly, a mouth that is small or does not open fully can make laryngoscopy difficult. The ability to place appropriately sized equipment into the oral cavity and to create a direct line of sight to the laryngeal structures can be compromised. Videolaryngoscopy will

improve visualization; however, navigating passage of the ETT can still be challenging when there is limited patency of the oropharyngeal space.

Restricted neck movement can also make it challenging to align the oral, pharyngeal, and tracheal axes to permit glottic visualization. A short neck exaggerates the acuity of the angle around the tongue toward the glottis. Videolaryngoscopy can facilitate seeing "around the corner" of the airway when upper airway axes cannot be aligned, but, again, tube passage can be challenging when the path of the ETT is not straight.

In patients with known or newly identified anatomic abnormalities as described earlier, the difficult airway algorithm should be used. The airway approach in these patients might include an awake (sedated) look to assess the degree to which the mouth can be opened, the tongue can be displaced into the mandibular space, or the larynx can be viewed with limited neck positioning (Table 27.3). If the awake look suggests passage of an ETT is likely to be difficult and time permits, neuromuscular blockade and RSI should be avoided or postponed until backup strategies are in place. Other potential approaches are reviewed throughout this book and summarized in **Table 27.7**.

TABLE 27.7 Specific Therapeutic Options for the Difficult Airway

The difficult airway algorithm applies to both children and adults with few exceptions; most notably, blind nasotracheal intubation is contraindicated in children younger than 10 y, as is surgical cricothyrotomy. Most children will not be cooperative with an awake, nonsedated look. Combitube, a useful adjunct in adults, is not manufactured for patients <48 in (122 cm) tall. Otherwise, the same approach and options are recommended for both children and adults.

There are a variety of airway devices for use in the pediatric patient. However, developing and maintaining competency is challenging with infrequent use, particularly in emergencies and by emergency practitioners. It is therefore probably best to choose fewer options but aim to gain the maximum experience with them. The following devices and procedures are listed according to appropriateness at different levels of clinical acuity.

Crash situation

Extraglottic devices

- Laryngeal mask airways
- Combitube (>48 in [122 cm] tall)
- King LT

Endotracheal (ET) intubation

- Traditional laryngoscopy
- Video laryngoscopy

"Surgical" airway

- Needle cricothyrotomy aka percutaneous needle tracheostomy (<5+ y)[a]
- Seldinger cricothyrotomy (>5 y)
- Surgical cricothyrotomy (>10 y)

Stable situation

- ET intubation (awake)[b]
- ET intubation (RSI)
- EGD
- Fiber-optic intubation

Blind nasotracheal intubation[b]	
Stable expectant management patients	
All EDs should have a plan in place for managing patients with disorders such as foreign body aspiration and epiglottitis. This usually requires prior agreement of consultants willing to respond immediately to those emergencies.	

[a]There are no published data to support the best means of ventilation in children following needle cricothyrotomy. Both transtracheal jet ventilation (TTJV) and BMV have been recommended. However, in the absence of clear supporting data and the prevalence of a high risk of barotraumas and complications related to TTJV, we suggest that practitioners utilize BMV with conversion to a more definitive airway as soon as possible. If a cricothyrotomy catheter has been placed (by Seldinger or surgical technique), BMV should be used.

[b]Rarely performed in pediatrics, greatest success in adolescents and adults.

When patients with risk factors for a difficult airway present in extremis or in crash situations, the clinician is left with no other options than those used in other patients. Fortunately, even when difficulty is predicted, straightforward approaches such as BMV or endotracheal intubation are usually successful and should remain the mainstay of therapy.

No Known Abnormality, with Unexpected Difficulty

Perhaps the greatest fear for most practitioners is to encounter unexpected difficulty after initiating airway management in a child *without* recognized congenital or acquired abnormalities. Based on data from large anesthesia registries, the incidence of *unanticipated* difficult intubation is vanishingly low, a reflection of the infrequency of difficult airways, as well as the ability of practitioners to use systematic strategies to effectively identify those patients with difficulty in advance. The management approaches for the *unexpected* pediatric difficult airway are similar to those for the expected difficult airway (see Table 27.3).

TIMING THE INTERVENTION

As is the case for adults, the patient's anticipated clinical course becomes a key determinant in deciding whether to actively intervene in the airway or to observe for possible deterioration. Table 27.6 groups disorders from both infectious and noninfectious causes according to timing of intervention based on anticipated clinical course. The expectant intervention group represents patients in whom the safest course of action may be a period of close observation, during which preparation is rapidly undertaken for definitive management were it to be required. In these children, evidence of clinical deterioration during observation will prompt active airway management in the ED. Alternatively, medical management may stabilize the patient such that invasive airway management can be avoided or allow sufficient time for transfer to a controlled environment such as the operating room and/or the recruitment of a multidisciplinary team with expertise in the management of difficult airways. Treatment outside of these ideal conditions may lead to untoward outcomes and should be avoided when possible.

The signs and symptoms of impending airway obstruction in children will guide the approach to the early intervention group. These disorders, if left to expectant management, have a greater potential for deterioration. An example, as discussed earlier, is the burn or caustic ingestion patient with early signs of injury such as voice change or faint stridor. Such symptoms may herald deterioration, although the degree and pace of progression cannot be predicted. However, it must be assumed that progression to the point of obstruction is possible, in which case intubation will be extremely difficult, if not impossible. For this reason, intervention sooner rather than later is recommended. Patients with compromised airways secondary to anaphylactic or anaphylactoid reactions (eg, angioedema) who do not respond immediately to medical treatment similarly require early intervention.

TIPS AND PEARLS

- Effective pediatric airway management is focused on anticipating and planning for difficulties.
- The systematic approach to identify the difficult airway in adults can also be used in children. In general, the highest yield features of the LEMON assessment in children include looking for obvious abnormalities (L for Look) and evaluating for upper airway obstruction (O for Obstruction).
- Most anatomically difficult pediatric airways are related to acute infectious or traumatic alterations to otherwise normal anatomy. Known congenital abnormalities are uncommon, and unexpected difficulty in children is very rare.
- Pattern recognition of the common presentations of acute infectious and noninfectious airway emergencies is important to the appropriate management.
- Management of children with difficult airways should follow the difficult airway algorithm, just as with adults. Most patients will still be managed with RSI and direct or video laryngoscopy.

EVIDENCE

What is the incidence of difficult and failed airways in children?

Although definitions and contexts vary, pediatric data demonstrate the rarity of difficult airways in children. Using a database of nearly 11 000 children being endotracheally intubated *in the operating room* using general anesthesia, the incidence of difficult laryngoscopy was just over 1%, although the rate climbed to nearly 5% in children less than 1 year of age.[1] Using another definition of difficult airway, a recent international multicenter study from the pediatric anesthesia literature again found that approximately 5% of children required more than two direct laryngoscopy attempts. Of these patients, 40% experienced desaturation to <90% during intubation; however, there was no increase in morbidity or mortality at follow-up.[2] A report of more than 1000 pediatric ED

intubations (age <15 years) from an airway registry revealed a first-attempt success rate of 83% and an ultimate success rate of 99.5%. There were no reported surgical airway procedures.[3]

What is the evidence for use of video laryngoscopy in pediatric emergency airway management?

Data regarding VL use in pediatric patients in the ED are currently limited. Currently, randomized trials of pediatric patients exist only in the anesthesia literature.[4] Data from single center retrospective studies of children in the ED are mixed. One study of approximately 500 patients showed improved first pass success without adverse events for the C-MAC compared to direct laryngoscopy (aOR = 1.6) but not for the GlideScope (aOR = 0.62).[5] However, a similarly sized pediatric ED study found a first pass success rate of 71% with direct laryngoscopy compared to 72% when using the C-MAC device.[6] A recent analysis of more than 600 pediatric intubations in the NEAR VII registry revealed higher first pass success with video than direct laryngoscopy (aOR = 5.5) even after controlling for use of optimizing maneuvers.[7] Importantly, none of these studies performed specific subanalyses on patients predicted to have difficult airways or addressed the potential benefit for providers whose prior experience with pediatric intubation may be limited or infrequent and who may benefit more from VL. There are, furthermore, additional benefits to use of VL related to quality assurance, real-time coaching, video-based teaching, or research that are not measured in these studies.

How reliable is the Mallampati scoring system in children?

The concept of evaluating the size of a child's tongue relative to his/her oral cavity remains important, although the data regarding the predictive value of Mallampati scoring are limited in pediatrics. Children, particularly those below school age, are unlikely to cooperate with testing. A "modified" approach is to use a tongue blade to facilitate mouth opening and depress the tongue. The original study in pediatrics included 476 patients, ranging from newborns to 16-year-olds. The predictive sensitivity of Mallampati testing was only 0.162. Importantly, of 16 patients with a poor view on laryngoscopy, 12 (75%) had Mallampati class 1 or 2 airways and were therefore not predicted to be difficult.[8] Conversely, a study of over 100 children who were able to comply with a Mallampati scoring found that of 7 with difficult laryngoscopy, only one had a high Mallampati score, yielding a very low sensitivity (14%).[9] Only one study has shown potentially valuable discriminatory value in which children with Mallampati scores of 3 and 4 had a higher incidence of difficult laryngoscopy (6.4%), compared to those with Mallampati 1 or 2 (0.4%).[1] Given the mixed data and the challenges of performing this examination, Mallampati testing is not frequently performed during emergent airway management in pediatrics.

Have clinical tools to predict difficult airways in children been validated?

The predictive merits of individual anthropomorphic measurements (eg, hyomandibular, thyromental, mandibular, and interdental lengths) and systematic clinical evaluation are

largely confined to adults and have not been well tested in children. One recent study confirmed that during bedside assessment, micrognathia (reported as frontal plane to chin distance), as shown in Figure 27.2, is the best predictor of difficult laryngoscopy, particularly in younger children.[9,10] These limited data, along with logic and anecdotal experience, support the idea that global assessment for features that might predict airway difficulty is important and should be routinely performed.

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CHAPTER 28

Foreign Body in the Pediatric Airway

Robert C. Luten

Steven Bin

Christyn F. Magill

INTRODUCTION

Foreign body aspiration (FBA) is a common cause of morbidity and mortality in children. Thousands of children are seen in emergency departments each year for choking-related episodes, and choking is a leading cause of death in young children. Children ages 1 to 3 years old are at the highest risk for choking and FBA. These children may choke on food substances given their incomplete dentition, immature swallowing coordination, and propensity toward distraction during meals. An infant's oral cavity is designed to move contents vertically, increasing the risk of choking and aspiration of solids. As children mature and develop, the oral cavity can move contents in a more transverse fashion for proper chewing. In addition, infants and toddlers are newly adapted to walking and tend to put everything in their mouths as they ambulate and explore. This increases their risk of unwitnessed choking events. Older children commonly aspirate things such as pins, coins, small toy parts, and pen caps, which they are holding in their mouths.

PRESENTATION

Children who have aspirated foreign material may present acutely following a *witnessed or reported* event. Families commonly report a choking or gagging episode, followed by sudden onset of coughing with unilateral

wheezing or decreased aeration. This represents the classic diagnostic triad for FBA in the mainstem or lower bronchi. When a foreign body becomes lodged more proximally, partial upper airway obstruction can lead to hoarseness or stridor. Complete obstruction of the trachea or larynx can occur either from mechanical blockage or from induced laryngospasm. The mortality with complete laryngeal obstruction approaches 50%.

Many children have *unwitnessed or unreported* aspiration events. Infants are preverbal and therefore unable to report when an event has occurred. Young children may not recognize the need to tell their parents. If immediate symptoms resolve, even caregivers may not recognize the significance of the event unless a provider directly asks about recent choking episodes. As a result, respiratory symptoms may be misattributed to illnesses such as asthma or croup. Subsequent recurrent pulmonary infections may lead to the delayed diagnosis of chronic FBA. This can occur weeks to months after the aspiration event.

For the purpose of this chapter, we will focus only on acute airway management in the context of known or suspected FBA.

TECHNIQUE

The approach to the management of FBA will differ depending on whether the obstruction is partial or complete and on the child's level of consciousness.

Partial Airway Obstruction

Children with FBA who can cough, cry, or speak are demonstrating adequate air exchange and, by definition, have an incomplete airway obstruction. Beyond infancy, children will naturally hold themselves in a position that maximizes airway patency. In addition, they possess a reflexive cough, which is the most effective means of clearing the airway. Manage these patients "expectantly." That is, do not attempt to relieve the partial obstruction because this could dislodge the foreign body and worsen the degree of obstruction.

Ideally, children with partial obstruction caused by FBA should be managed in the operating room if possible. If an operating room or pediatric expert resources are unavailable for immediate management, an alternative

plan must be initiated. Obtain a variety of appropriately sized equipment for foreign body removal as well as definitive airway management in the event that the child progresses to complete airway obstruction (discussed later). A provider should decide on and prepare for a primary airway management plan and have a contingency in mind if the initial plan fails.

Attempts at removal of the foreign body for children with partial airway obstruction are rarely performed in the emergency department. Children are unlikely to cooperate with efforts to remove an airway foreign body even with effective topical anesthesia. Furthermore, unintentionally placing a laryngoscope blade too deeply in small children will risk placing direct pressure on the foreign body, which can further obstruct the airway. Therefore, in most cases, the child should be allowed to continue to attempt to clear the foreign body reflexively as long as possible or until an operating room is available. Only when the patient is showing signs of tiring or is progressing toward complete obstruction should attempts at removal be made. In such circumstances, sedation with ketamine (1-2 mg/kg IV or 4 mg/kg IM) reliably produces dissociation while maintaining respiratory drive and airway reflexes. Once sedated, the laryngoscope is inserted methodically, while the provider maintains anatomic visualization attempting to identify any supraglottic foreign body.

If the patient progresses to complete obstruction, either because of unavoidable progression or as a result of attempts at removal, immediate intervention is required.

Complete Airway Obstruction

When an awake child with a suspected FBA loses the ability to phonate or cough, this indicates complete airway obstruction. Chest wall movement will persist with attempted respiratory efforts; however, there will be no air movement. Conscious children will appear scared, although infants will not reliably place their hands to their neck to signify choking, as older children or adults will. Instead, they will often raise clenched fists above their heads with eyes wide open as an expression of distress.

Use pediatric basic life support techniques immediately in the conscious patient with complete airway obstruction from FBA. The goal is to generate intrathoracic pressure to expel the foreign body from the airway. In infants,

this is most safely attempted with the child in a head down position, using repeated cycles of back blows and chest compressions, five per cycle. Subdiaphragmatic abdominal thrusts (the Heimlich maneuver) are not recommended in infants because of the risk of accidental injury to the relatively large liver protruding beneath the costal margin. In children older than 1 year, the Heimlich maneuver is recommended, just as with adults. Repeat these initial maneuvers until either the foreign body is expelled or the patient becomes unresponsive.

There is no role for attempting instrumentation to remove the foreign body in a conscious child who will not cooperate with removal. With complete obstruction of the airway, rapid oxygen desaturation will render the patient unconscious within 1 or 2 minutes, at which point attempts at removal can be made. For the child who presents already unconscious, the oropharynx should first be examined for a visible foreign body. If something is seen, it should be removed directly. If no foreign material is seen, a blind oropharyngeal finger sweep should *not* be performed. In the emergency department, the immediate maneuver is laryngoscopy for possible foreign body visualization and removal. This is exactly analogous to the adult patient (see Chapter 44). The administration of a neuromuscular blocking agent is *not* indicated for the initial attempt. Only if children have a clenched mouth or other signs of muscle tone that is prohibiting laryngoscopy will it be necessary to use a rapid-onset neuromuscular blocking agent. If the foreign body can be identified under direct laryngoscopy, it should be removed using Magill or alligator forceps. Care must be taken to avoid advancing the foreign body to a position where it becomes more tightly lodged or to a location where it is no longer retrievable. Similarly, organic material may be friable, and although rapid resolution of complete obstruction is the immediate goal, care should be taken, when possible, to grasp gently to avoid creating smaller fragments that can fall deeper into the tracheobronchial tree.

If BLS maneuvers and removal with laryngoscopy and Magill forceps are unsuccessful, attempts should be made to advance the foreign material distally into either mainstem bronchus using a stylet and endotracheal tube. First, the standard “lip-to-tip” distance should be identified using the Broselow-Luten tape, Airway Card mobile device app, or other formulas. It may be helpful to tape or mark this distance on the endotracheal tube.

Intubate the child with the endotracheal tube (stylet in situ) advanced as deeply as possible. The obstructing material will be pushed down the trachea, past the carina, and into a mainstem bronchus, most often the right based on a shallower take-off angle. Then withdraw the tube back to the standard “lip-to-tip” distance previously marked on the tube. The foreign material will now be completely obstructing one bronchus, with effective ventilation now possible through the other, effectively moving from complete obstruction to single lung ventilation (see **Fig. 28.1**). If there is improved ventilation but high resistance following this maneuver, soft material such as food substances may have become lodged within the endotracheal tube tip, preventing easy passage of air. If this occurs, replacement of the endotracheal tube, using the appropriate insertion depth, provides the most effective means to ventilate the patient through the patent mainstem bronchus.

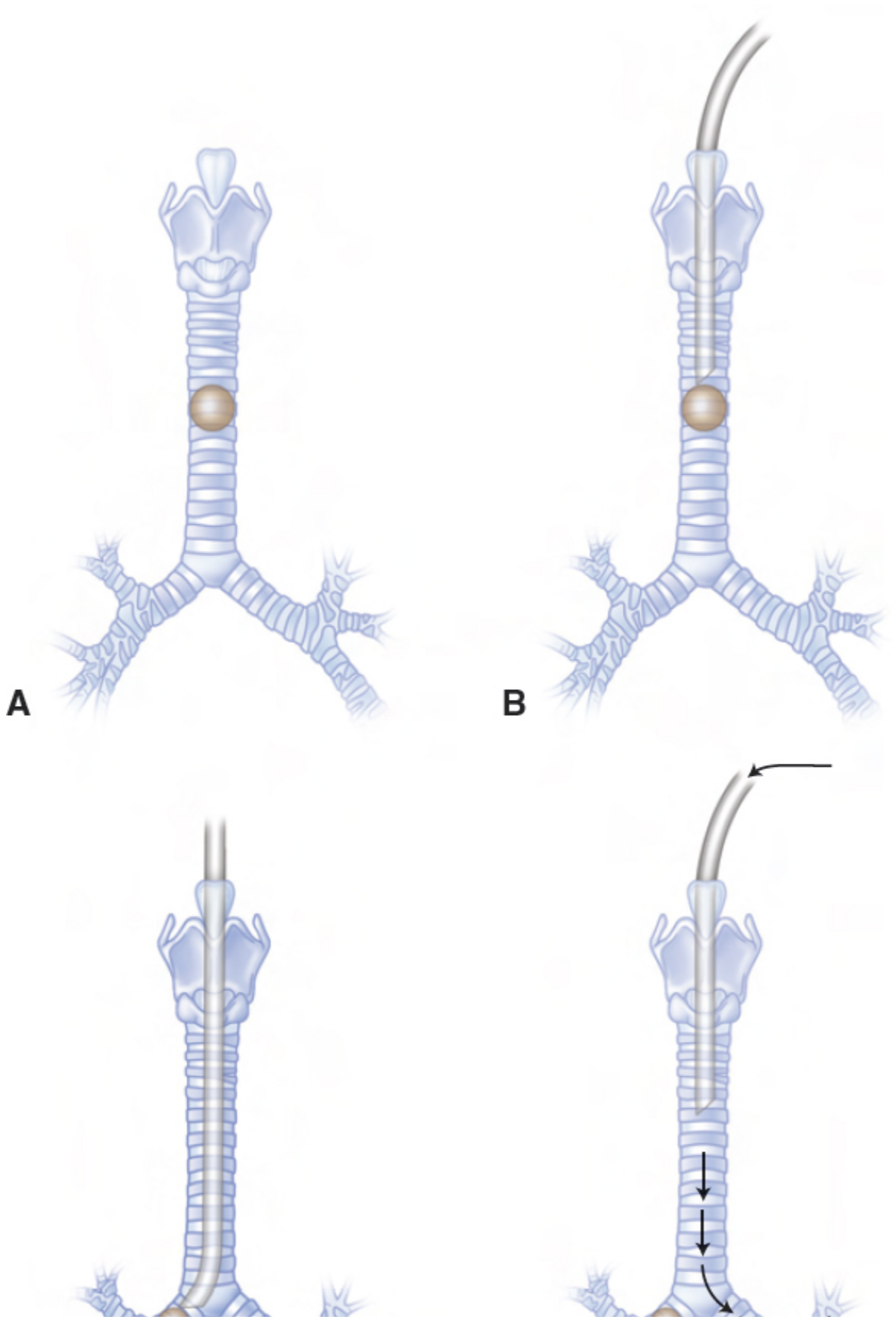
A
B

Figure 28.1: Advancing a foreign body lodged in the trachea. A: Foreign body lodged in the trachea. B: Endotracheal tube may meet resistance at the level of the foreign body. C: Endotracheal tube is advanced to push the foreign body into a mainstem bronchus. D: Endotracheal tube is pulled back to the appropriate "lip-to-tip" distance, and the unobstructed lung is ventilated.

A percutaneous approach (eg, needle cricothyrotomy) is rarely indicated in FBA. Details of this approach are provided in Chapter 26. Needle cricothyrotomy will be successful only if the needle entry site is distal to the obstruction (eg, a foreign body just below the vocal cords at the cricoid ring). If the foreign body cannot be visualized during attempts at laryngoscopy, it is unlikely that a percutaneous approach will be distal to the object, rendering the procedure ineffective. Ventilation strategies following percutaneous airway techniques are reviewed in Chapter 26. In patients with complete airway obstruction, it is important to remember that no air can exit through the glottis into the pharynx. The only means for exhalation is through the narrow lumen of the catheter; therefore, the risk of barotrauma increases following each delivered breath.

Both forced intubation and needle cricothyrotomy are temporizing measures designed to reestablish some degree of oxygenation and ventilation. When successful, the patient can then be taken to the operating room for removal of the foreign body with a bronchoscope or by thoracotomy as needed.

An overview of the stepwise approach to managing FBA in children is presented in **Figure 28.2**.

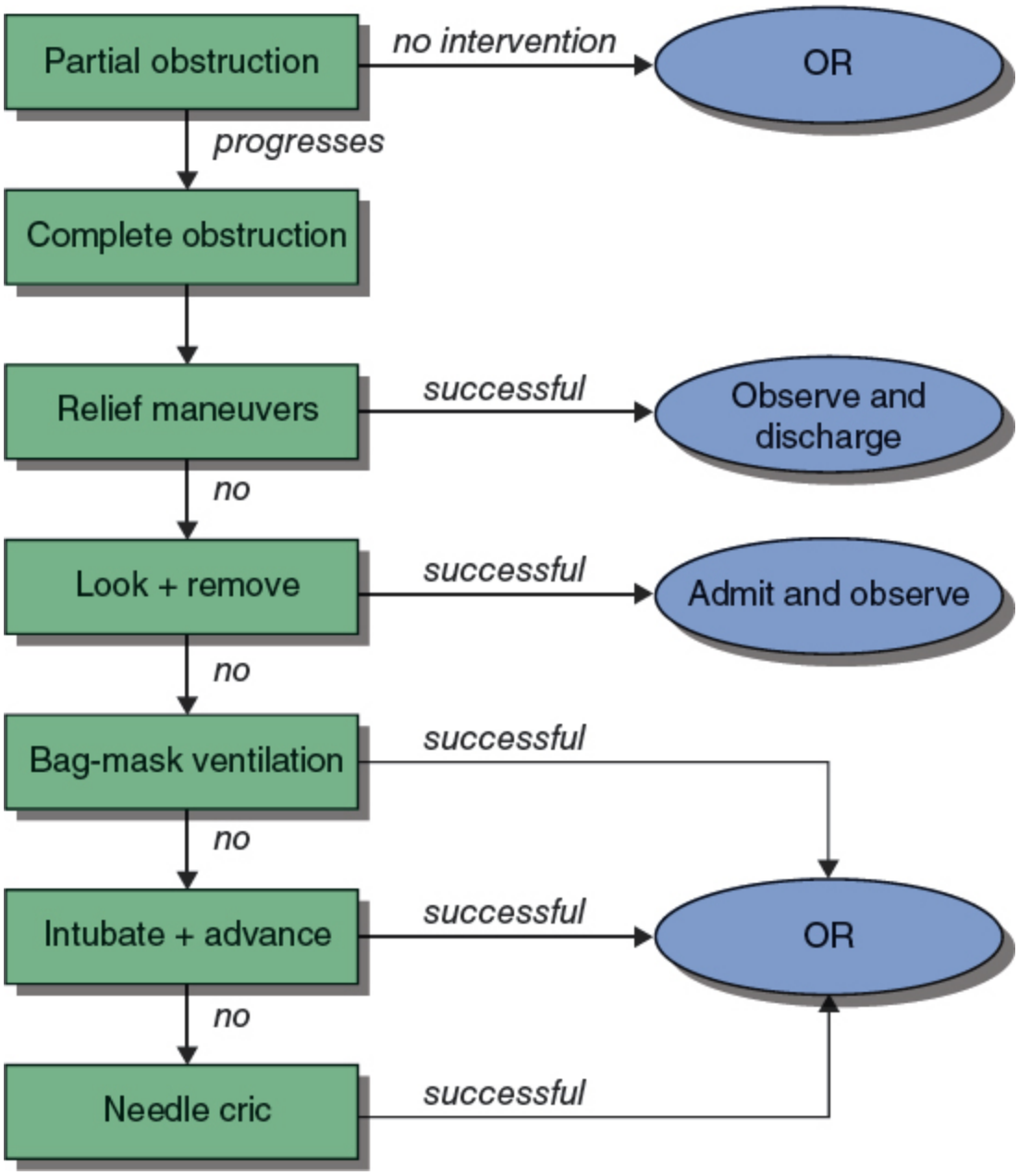

Figure 28.2: Stepwise approach for the management of an aspirated foreign body.

TIPS AND PEARLS

- Many aspiration events in children are unwitnessed, and young children are incapable of verbalizing what has happened. Consider aspiration in any infant/toddler with acute onset of respiratory distress.

- The ideal location for removal of a foreign body from a pediatric airway is the operating room. Recruit necessary personnel and resources as early as possible.
- Reflexive cough is likely to be the most successful mechanism for clearing a foreign body from a partially obstructed airway. Avoid interfering with an alert child who is sitting in a position of comfort and coughing.
- In the emergency department, if there is high suspicion for complete obstruction from a FBA, laryngoscopy for possible direct removal should be attempted *before* positive-pressure breaths to avoid advancing the foreign body to an unreachable position. If equipment is not immediately available, bag-mask ventilation may stent open the airway and allow small amounts of oxygen around the foreign material to support oxygenation until attempts at laryngoscopy for visualization and removal are made or intubation to advance the foreign material can be performed (see **Fig. 28.3**).

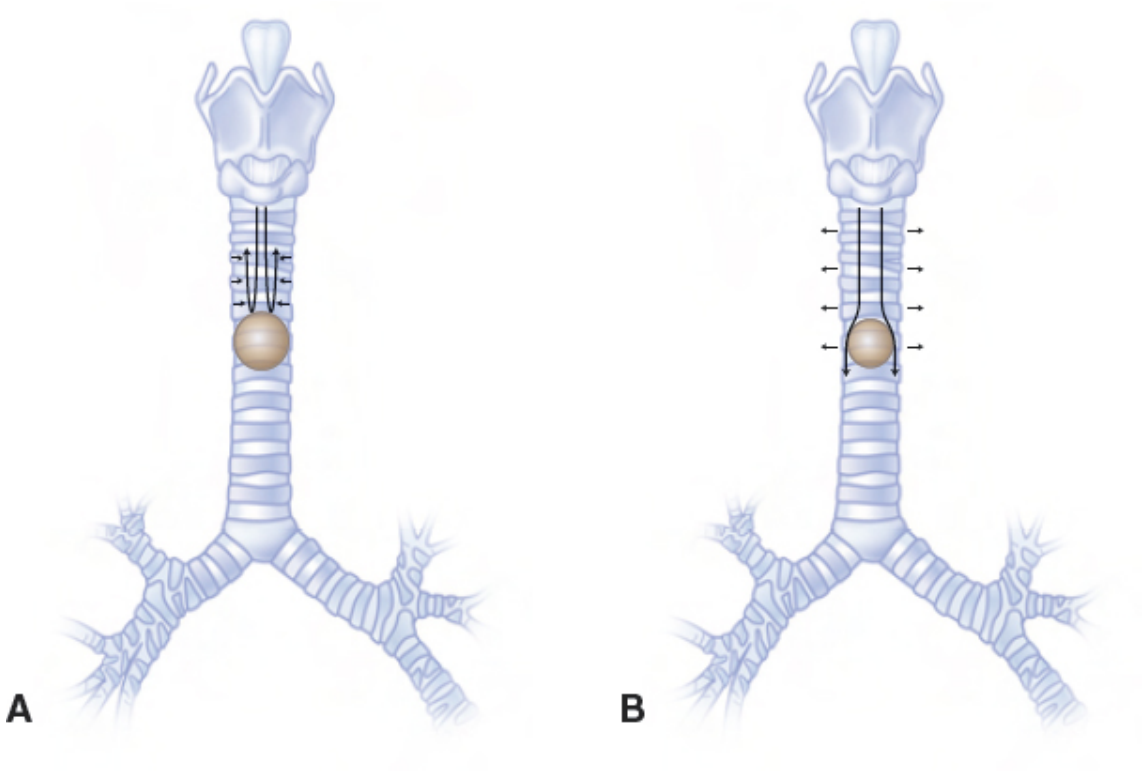

Figure 28.3: A: With spontaneous respiratory effort, lower pressure in the airway pulls the walls inward, tightening the seal preventing airflow past the foreign body. B:

With positive-pressure ventilation, the walls of the airway are pushed outward, and a small amount of airflow around the foreign body may be possible, serving to temporize oxygenation until definitive management is possible.

- Avoid the Heimlich maneuver in children younger than 1 year to prevent inadvertent injury to the liver.
- Needle cricothyrotomy is unlikely to be beneficial in any child in whom the foreign body cannot be visualized above or immediately below the glottis and therefore should not be attempted in these patients.

EVIDENCE

How common is FBA in children, and what do they aspirate?

The Centers for Disease Control and Prevention (CDC) data show that more than 153 000 children under 10 years of age were seen in emergency departments in 2019 for nonfatal, unintentional foreign body injuries, including choking-related episodes.[1] More devastatingly, 1330 children under 10 years of age died from choking and unintentional suffocation. Choking/suffocation is the leading cause of unintentional death in children under 1 year of age.[1] Data suggest that choking on food alone causes the death of approximately one child every 5 days in the United States.[2] Younger children typically choke on food items.[3,4] An infant's oral cavity is designed to move contents vertically, rather than the more mature transverse motion needed for processing solid food.[5] Older children more commonly aspirate things such as pins, pen caps, coins, and small toy parts, which they are holding in their mouths, although variability exists by country.[4]

Where in the airway are most pediatric FBA?

Most airway foreign bodies are located in the proximal airway (larynx, trachea, and even mainstem bronchus). Data show that as the mean age of the child increases, the location of the FBA becomes more distal in the airway. Additionally, mortality increases as the location of the FBA becomes more distal.[6]

What is the presentation of a child who has aspirated?

The classic triad of a child who has aspirated a foreign body is choking or gagging, wheezing, and asymmetric breath sounds. However, only ~ 57% of children will have this classic presentation.[6] A high index of suspicion is required to diagnose FBA when there is an unwitnessed or unknown event.

Should I perform a blind finger sweep if there is concern for complete obstruction?

Rapidly removing a completely obstructing foreign body is paramount. In the conscious patient, the immediate intervention should be the Heimlich maneuver (for children >1 year old) or back blows and chest compressions (for children <1 year old).[7] If the victim becomes unresponsive, looking in the mouth and removing any visible foreign body is recommended. Data from case reports suggest that blind finger sweeps may advance the foreign body farther into the airway and may cause oropharyngeal trauma and should therefore not be performed.[7-9]

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Section VII

EMS Airway Management

29 Introduction to EMS Airway Management
30 Techniques in Prehospital Airway Management
31 Difficult and Failed Airway Management in EMS
32 Controversies in EMS Airway Management

CHAPTER 29

Introduction to EMS Airway Management

Michael J. Keller

Michael T. Steuerwald

Estêvão M. Lafuente

THE CLINICAL CHALLENGE

The prehospital setting presents unique challenges to all patient care, not the least of which is airway management. Despite these challenges, the core concepts of emergency airway management are the same in the prehospital and hospital environments: maintaining oxygenation and ventilation while mitigating complications. However, the patient's disease process is often undifferentiated; resources and equipment may be more limited than in the hospital setting; and there may be issues of patient access, lighting, adverse weather, confined space, turbulence or road vibration, and provider safety. When these factors are taken in the aggregate, it is unreasonable to expect that out-of-hospital airway management will look identical to in-hospital airway management. Furthermore, airway management will not look the same in any two emergency medical services (EMS) systems owing to differences in provider levels of training, scope of practice, medical direction, treatment guidelines, transport times, equipment, and many other factors.

The prehospital setting is notoriously unforgiving for any high-risk, high-complexity, and low-volume procedures, which include most airway interventions. These risks may be offset by careful planning, continuing education, use of algorithms and checklists, quality oversight, and strong medical director involvement. System administrators, medical directors,

educators, and providers must all be committed to rigorous evaluation of the care delivered, patient outcomes, and the latest literature and how it applies to that system's practice.

APPROACH TO THE AIRWAY

EMS airway management must focus on rapid assessment and simultaneous interventions. The goals are optimization of oxygenation and ventilation while minimizing complications such as hypoxia, hypotension, and aspiration. This must occur while facilitating extrication and transport along with performance of any other critical treatments that may be indicated. Even one episode of hypoxia or hypotension increases mortality, and the combination is much worse.[1] In general, the least invasive and time-consuming airway interventions that achieve the stated goals are preferable, because they keep "forward momentum" to the hospital.

The following are some examples that highlight the above philosophy:

- A 55-year-old presents for an exacerbation of left-sided congestive heart failure with pulmonary edema, resulting in respiratory distress and peripheral oxygen saturation of 75%. The primary issue is oxygenation. If supplemental oxygen delivery in a position of comfort does not rapidly correct the problem, then administration of nitroglycerin and titration of continuous positive airway pressure (CPAP) along with initiation of transport are appropriate in most EMS systems. Administration of diuretics and intubation, if necessary, may often be deferred to the hospital unless transport times are prolonged.
- A 14-year-old female thrown from a horse initially presents with a Glasgow Coma Scale (GCS) of 13, and a flight crew is dispatched. While transporting the patient, her mental status deteriorates with a noted rise in blood pressure and drop in respirations. Because of the confined space of the aircraft, the flight crew elects to perform a rapid sequence airway (RSA) procedure with placement of an extraglottic device (EGD) rather than a rapid sequence intubation (RSI). The patient receives analgesia, the ventilator is placed and titrated to maintain normal $ETCO_2$, a gastric tube is inserted via the EGD channel and attached to suction, and oxygen is titrated down until the

saturation falls just below 100%. On arrival at the ED, the patient is taken directly to the computed tomography (CT) scanner, an epidural hematoma is detected, and the EGD is exchanged for an endotracheal tube using a flexible endoscope while awaiting arrival of the neurosurgeon.

- A 27-year-old male with multisystem blunt trauma presents with a GCS of 11, a systolic blood pressure of 90, and a saturation of 85%. The first actions are to roll the patient to clear the airway, apply supplemental oxygen, assess for tension pneumothorax, and start an IV for fluid administration, all while moving toward the hospital. If the provider addresses hypotension and hypoxemia, avoids hyperventilation, and makes reasonable attempts to prevent further aspiration, the goals have been met even though the airway has not been definitively secured. If the provider has time and scope of practice allows it, medication-facilitated airway management (MFAM) could be considered. However, as discussed later, the evidence of benefit is limited, whereas the potential for harm is real if the patient becomes hypoxemic, hypotensive, or hypocarbic because of the procedure.

In each of these cases, the providers focused on the most efficient means of establishing oxygenation and ventilation, and minimizing complications, not on any one procedure. Invasive airway management, including MFAM, has a role in prehospital care if it is done carefully and judiciously with close supervision and medical oversight. It is our belief that care for each patient should be individualized based on the presenting clinical condition and anticipated clinical course, transport time, predicted difficulties, and the provider's experience and scope of practice. It is critical to keep in mind that many studies and reviews have failed to demonstrate improved patient outcome from prehospital endotracheal intubation and that several have demonstrated worse outcomes (see Chapter 32).

The indications for prehospital intubation are the same as for hospital-based care, with appropriate consideration of resource constraints, transport mode and time, and the option to provide less-invasive temporizing care in some circumstances. In addition, the primary question for EMS providers is not whether the patient "needs intubation" but whether they need any form

of invasive airway management before arrival at the hospital. We seek to provide a reproducible approach via the EMS airway algorithm presented in Chapter 31.

LEVELS OF TRAINING AND SCOPE OF AIRWAY PRACTICE

Although it is impossible to consider EMS in all countries on all continents, we can use the American system as a representative model. Modern EMS systems in the United States of America (USA) are complex and evolutionary models can vary greatly from state to state and jurisdiction to jurisdiction. Although specific scope of practice and medical privileges are granted by individual state authorities and agency or entity medical direction, the US federal government has expended considerable effort to define a national model for state governments to adopt in part or whole. The National Highway Traffic Safety Administration (NHTSA) published the National EMS Scope of Practice Model 2019 with corresponding new National EMS Education Standards published in 2021.[2,3] The intent of this "Practice Model" is to be a guide for states in developing their scope of practice legislation, rules, and regulations. The 2019 document outlines the individual credential levels as follows: (In increasing scope of practice order from lowest to highest)

- Emergency Medical Responder (EMR)
- Emergency Medical Technician (EMT)
- Advanced Emergency Medical Technician (AEMT)
- Paramedic

According to the 2019 scope of practice document, only 76% of states were using the historical Practice Model for EMR, and 88% were using the Practice Model for AEMT. Thus, it should be assumed that various psychomotor skill privileges will vary across state jurisdictions. A few state privileges went beyond the Practice Model related to airway management and basic adjuncts. For example, although the Model did not recommend EMR personnel using nasopharyngeal airway (NPA) adjuncts, many states included the use of NPA in their state protocols. Another common deviation related to the use of extraglottic devices. Not only do most states allow

EMT providers to use EGDs, but the use of them is especially encouraged in cardiac arrest scenarios. Of note, the 2019 document does not use traditional nomenclature to differentiate skill set privileges into categories such as Basic Life Support and Advanced Life Support. Rather, it outlines recommended psychomotor skill sets for each recognized level based on education, competency, state licensing, and credentialing by local medical direction (**Table 29.1**).

TABLE 29.1 Select Airway Management and Airway/Ventilation Skill Set[a]

Skill—Airway/Ventilation	EMR	EMT	AEMT	Paramedic
Airway—nasal airway		X	X	X
Airway—oral airway	X	X	X	X
Airway—supraglottic device			X	X
Bag-valve-mask (BVM)	X	X	X	X
CPAP		X	X	X
Cricothyrotomy				X
End tidal CO_2 monitoring and interpretation of waveform capnography			X	X
Head tilt—chin lift	X	X	X	X
Endotracheal intubation				X
Jaw Thrust	X	X	X	X
Airway obstruction—dislodgement by direct laryngoscopy				X
Airway obstruction—manual dislodgement techniques	X	X	X	X
Oxygen therapy—high-flow nasal cannula				X
Oxygen therapy—nasal cannula	X	X	X	X
Pulse oximetry		X	X	X
Suctioning—upper airway	X	X	X	X
Suctioning—tracheobronchial of an intubated patient			X	X

[a]*Representation of the Interpretive Guidelines published in the 2019 National Association of State EMS Officials's* National EMS Scope of Practice Model 2019 *(Report No. DOT HS*

812-666) as it relates to the arena of select airway management and airway/ventilation skill set.

With respect to MFAM techniques (eg, RSI), a study in 2016 found profound differences across all 50 US states and the District of Columbia.[4] This is an area of ongoing controversy (see Chapter 32). This article, published in the *American Journal of Emergency Medicine*, discovered that only 35 states have statewide EMS protocols. Eighteen of those 35 states have statewide protocols addressing the use of medication-facilitated intubation. The authors also found one state that did not possess statewide general patient care protocols but that did have a statewide protocol to specifically address medication assisted intubation. Of the original 18 states mentioned previously, one state used sedation-only intubation protocols, 11 allowed adult and pediatric MFAM, whereas 7 limited the scope of practice to adults only. Of the 18 states, 8 mandated specific protocol training, including skill lab and mechanical ventilation teaching, before the scope of practice could be enacted.

MECHANISMS FOR MAINTENANCE OF AIRWAY COMPETENCY

The National Association of EMS Physicians (NAEMSP) published a position statement in January 2022 that helps providers better understand the comprehensive nature of EMS airway management training and education.[5] The authors correctly point out that airway management extends far beyond a narrow focus on psychomotor skills to include an appreciation of pathophysiology, clinical judgment, and higher-order decision-making. Optimization of patient outcomes should be valued over performance of individual airway management skills.

The development of clinical skills is only one part of a comprehensive airway management training program. Comprehensive airway management is greater than the sum of its parts. It includes knowledge of the strengths and weaknesses of different techniques but also clinical decision-making acumen to choose the right technique for the right patient at the right time. As the position statement points out, any comprehensive airway management training program must engage the three key domains of learning: psychomotor, cognitive, and affective to ensure internalization of

knowledge, skills, and attitudes necessary to implement a comprehensive approach.

It has become harder for initial and continuing education training programs to make supervised live intubations available because of a variety of issues (eg, an overload of learners in the surgical suites, fewer intubation procedures being performed in the surgical environment, and concern of liability). Because of the limited availability to live intubations, training centers must become proficient in the development of scenario-based learning, as well as appropriate use of high-fidelity simulators to prepare practitioners for competent field performance of all airway management techniques.

Further, field intubation rate per EMS provider credentialed for that skill may be very low depending on their individual practice situations. In one published article from Europe, an EMS service with a little over 26,000 patient contacts resulted in 256 orotracheal intubations. Among the agency paramedics, the average number of annual intubations was 4.2, which varied from zero to 12.[6] Another report from a small southern California town in the United States, serving a population of 32,000 with an annual response of nearly 3100 emergency calls for help, cited that the department had completed 23 intubations in 2008. That number had fallen to just 2 intubations in 2016 owing to changes in American Heart Association (AHA) standards regarding airway management during cardiac arrest.[7] The reality of decreasing frequency of prehospital intubations demands the development of a comprehensive training program to ensure competency for this very high-acuity, low-frequency invasive procedure.

HUMAN FACTORS IN PREHOSPITAL AIRWAY MANAGEMENT

The clinical challenges discussed earlier increase provider stress. The physiologic responses to stress include reduced situational awareness, reduced memory recall, emphasis on intuition over analytic thinking, and decreased fine motor skills. Together, these responses predispose to medical error. Recognizing, understanding, and managing human factors is important for patient safety, efficiency, and provider health. Opportunities to modify human factors in airway management include, but are not limited

to, education incorporating simulation and stress inoculation, deliberate practice, and cognitive off-loading tools. These tools may include simple mnemonics, algorithms, phone applications, pediatric equipment and medication dosing schemes, emergency action drills, airway checklists, and briefings.

A briefing is intended to ensure all participants understand the primary strategy, any anticipated issues, plans to mitigate these anticipated issues, and emergency action plans. A checklist, on the other hand, includes a limited number of very specific high-yield items addressed in a challenge-and-response format. Checklists have been used in many health care and non-health care settings and should be strongly considered for out-of-hospital airway management. In a 2019 observational study, researchers found that applying preintubation checklists were associated with increased success at first and second intubation attempts. Moreover, this study found that esophageal misplacements were significantly more common in the nonchecklist group (2.2% vs 0.3%).[8] In practice, many prehospital airway checklists have incorporated items that would traditionally fall into a briefing because the entire procedure happens in a short time span. A sample briefing and checklist are shown in **Figure 29.1** and a hybrid checklist/briefing in **Figure 29.2**.

UNMH Lifeguard Airway Management Tool

Airway briefing

Before arrival or prior to procedure setup

- ❑ **Establish optimal patient position**
- ❑ **Initiate preoxygenation strategy**
  - Regular NC + NRB or BVM/PEEP or BiPAP
- ❑ **Address potential difficulties**
  - Anatomy/spinal precautions
  - Physiology: BP/volume, hypoxia, Rt heart failure, acidosis, hyperdynamic
- ❑ **Verbalize primary plan:** Crash, RSI, DSI, RSA, Awake, SALAD
  - Device: VI hyperangulated, VL standard + bougie, DL + bougie
- ❑ **Verbalize backup plan:** BMW, EGD, surgical
- ❑ **Verbalize drugs and doses:** induction, paralysis, pressor, postintubation

Airway time-out checklist

Immediately before intubation

❑ **Suction...**	On and ready
❑ **Preoxygenation...**	NRB/BVM and nasal cannula on at __ lpm
Equipment/Personnel	
❑ **Boudie/IGel/NPA/OPA/BMW+PEEP...**	Size ____ iGel ready, PEEP at ___
❑ **Monitor and end tidal CO_2...**	Monitor on. Capnography ready
❑ **Access...**	IV/IO working
❑ **Positioning...**	Optimized
❑ **Assistant(s)...**	Assigned/briefed
Confirm Medications	
❑ **Induction...**	___ mg of _____ ready
❑ **Paralytic...**	___ mg of _____ ready
❑ **Push dose pressor...**	___ µg/mL of ____ ready
Resuscitation	
❑ **Hemodynamics...**	Last BP ___
❑ **Oxygenation...**	Current SpO_2 ___
❑ **Other physiologic difficulties**	Addressed

❑ **PUSH medications. PRESS record—Glidescope. QUIET for induction.**

Figure 29.1: Airway management tool used during preparatory phase and immediately before enacting an airway procedure. (Courtesy of University of New Mexico Hospital Lifeguard.)

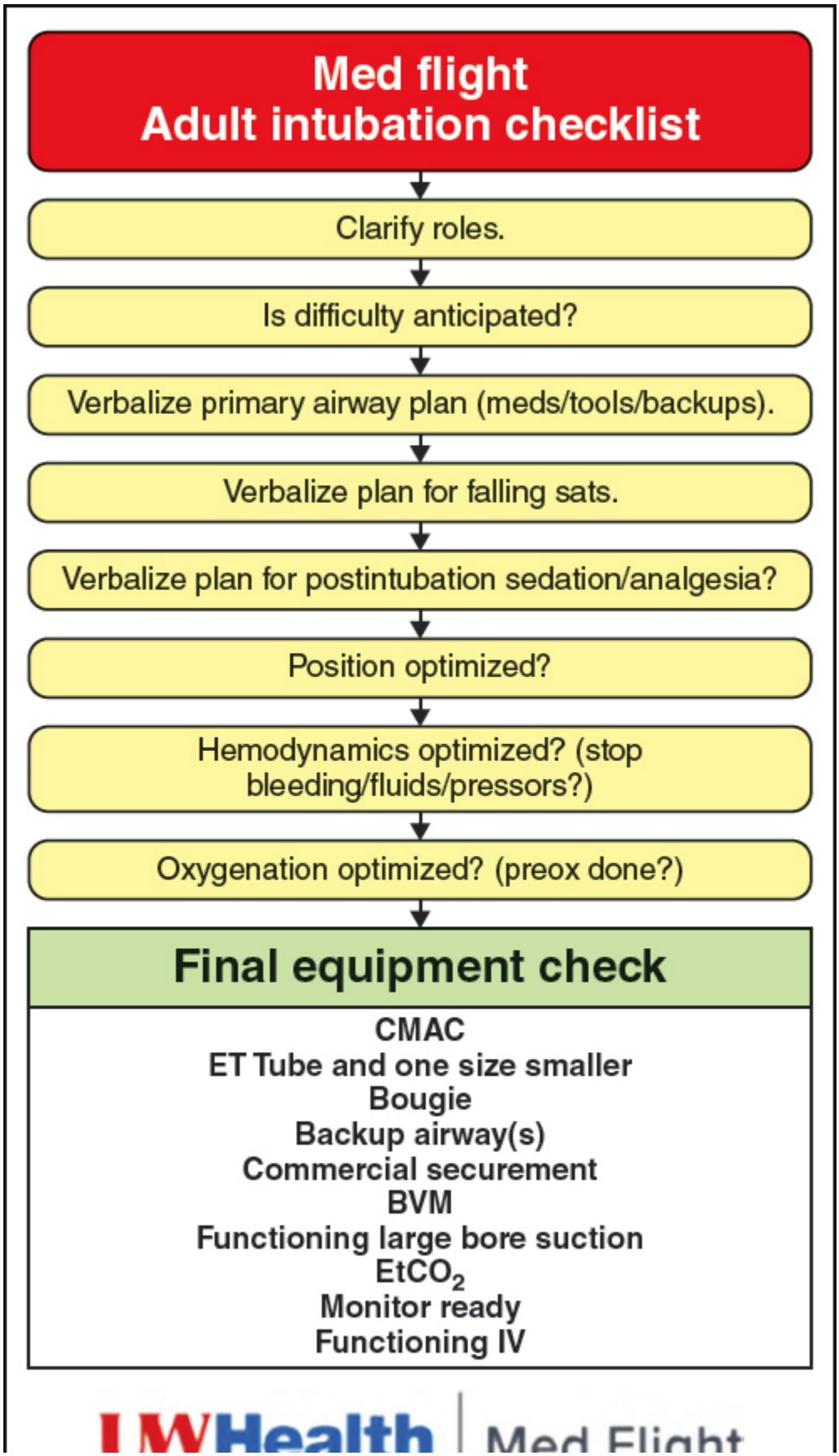
Med flight
Adult intubation checklist
Clarify roles.
Is difficulty anticipated?
Verbalize primary airway plan (meds/tools/backups).
Verbalize plan for falling sats.
Verbalize plan for postintubation sedation/analgesia?
Position optimized?
Hemodynamics optimized? (stop bleeding/fluids/pressors?)
Oxygenation optimized? (preox done?)
Final equipment check
CMAC
ET Tube and one size smaller
Bougie
Backup airway(s)
Commercial securement
BVM
Functioning large bore suction
EtCO2
Monitor ready
Functioning IV
IWHealth | Med Flight

Figure 29.2: Adult intubation checklist. Crews use this document at the beginning of airway management for briefing purposes, and then again immediately preprocedure for final check purposes. (Courtesy of University of Wisconsin Health Med Flight.)

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CHAPTER 30

Techniques in Prehospital Airway Management

Chivas Guillote

Darren A. Braude

Airway management in the prehospital environment is fraught with challenges. This chapter focuses on unique management techniques and variations of traditional techniques to overcome these challenges. Many of these techniques also apply in more conventional settings. The information in this chapter is not intended to be prescriptive in nature but recognizes there are variations in regional practice, state laws, and medical direction.

LOCATION/ENVIRONMENTAL FACTORS

When possible, patients should be moved to a secure, private, warm, shaded, well-lit, spacious environment prior to airway management. If confined by a small area, it may be necessary to move the patient to a larger room. If working outdoors, moving the patient to the ambulance where all the operator's tools are instantly available may be preferable. Certain scenarios require management of the patient right where they are found; for example, if the patient is in cardiac arrest, if they are entrapped, or if there is no optimal place close by, or if moving the patient is deemed unsafe.[1-3] In these circumstances, rescuers should limit airway procedures to only those that are necessary. This may require deferring invasive airway management until care can be safely rendered.[4]

PATIENT POSITIONING FOR AIRWAY MANAGEMENT

Patient positioning is one of the challenges differentiating prehospital from hospital practice. Prehospital patients are frequently found on the floor,

recumbent on soft surfaces, or entrapped. These unique positions may make it difficult to obtain optimal positioning for preoxygenation and airway interventions. Providers can handicap themselves by trying to manage the patient in the position in which they are found. In general, rapid attempts to achieve better positioning will yield significant benefits for the provider and the patient.[5-8]

Whenever possible, patients found on the floor or in other suboptimal positions should be moved to a stretcher/pram before airway management (**Fig. 30.1**). This practice has the advantage of improving airway management and avoids having to move the patient onto the stretcher while intubated, with the associated risk of tube dislodgement. Achieving a sniffing or ramped position can be challenging when manpower, towels, blankets, and sheets may be in short supply.

Figure 30.1: Placing the patient on the EMS stretcher and lifting it up allows for intubation to occur at an optimal height.

We have started to adopt an alternative position—for those adult patients not in cervical precautions—whereby the patient's head is slid off the end of the bed and then the head of the bed is then lifted 20° to 45° (**Fig. 30.2**). This position allows for off-loading of the diaphragm to enhance respiratory physiology and achieves ear-to-sternal notch alignment by head extension alone without forward flexion.

Figure 30.2: A patient (without concerns for cervical injury) is slid until their head is off the end of the bed (A), and then the head of the bed is raised 20° to 45° to achieve desired ear-to-sternal notch positioning and off-loading of the diaphragm (B). The feet may need to be raised first (modified v-position) to keep the patient from sliding down the bed. Photos C and D show how this position mimics a traditional ramped position.

For patients in cardiac arrest, it may not be feasible or desirable to place the patient on the stretcher. In such cases, towels, clothing, or a small piece of equipment may be placed behind the head to achieve the classic sniffing position (**Fig. 30.3**). It is more challenging to create a ramped position for

an obese patient on the ground, because this requires more padding and can interfere with chest compressions. Ideally, the obese, supine patient not in cardiac arrest should be moved to the stretcher and positioned with additional padding if needed (**Fig. 30.4**). For the obese, supine patient in cardiac arrest, ventilation with an extraglottic device (EGD) avoids the need for perfect positioning. If laryngoscopy is necessary, as when foreign body removal is required or ventilation via EGD is not effective, an attempt with a sniffing position is reasonable. If this does not create an adequate view for laryngoscopy, two providers can replicate a ramped position by grasping the patient's outstretched arms from the front and pulling them into position (**Fig. 30.5**). This procedure interrupts chest compressions but can only be maintained for a few seconds.

Figure 30.3: Achieving sniffing position with improvised supplies, in this case firefighter bunker gear and IV bags.

Figure 30.4: Achieving a ramped position for an obese patient using a combination of padding and elevation of the head of the stretcher. Photo courtesy of JEMS.

Figure 30.5: Assistants are lifting a patient's arms to demonstrate how to quickly and briefly position a patient lying on the ground for intubation without having to build a ramp.

PATIENT MONITORING

General monitoring for patients undergoing airway procedures is the same in the hospital and prehospital settings. Oxygen saturation, blood pressure, and end-tidal CO_2 monitoring are essential. The seminal San Diego RSI study from 2003 demonstrated that busy providers will not be able to

accurately recognize the incidence and duration of desaturation events.[9] We recommend the ability to download continuous vital sign data from all airway encounters for quality assurance review. For both clinical care and medicolegal documentation, it is imperative that all patients undergoing invasive airway procedures have capnography immediately available for confirmation of placement and monitoring of ventilation. This means that the monitors must be brought to the bedside or the patient brought to the monitors before airway procedures.

ESSENTIAL SKILLS IN PREHOSPITAL AIRWAY MANAGEMENT

Bag-Mask Ventilation

Bag-mask ventilation (BMV) is discussed extensively in Chapter 12. Although BMV is a fundamental airway skill taught to emergency medical services (EMS) providers of all levels starting at the emergency medical responder level, it can be very difficult to perform in the prehospital setting for a variety of complex reasons. Patients often present with multiple predictors of difficulty from the MOANS mnemonic (see Chapter 2), access and positioning may not be optimal, personnel may be limited, and, perhaps most importantly, the procedure is often relegated to the least experienced provider. Strategies to mitigate these issues include emphasizing optimal technique (proper positioning, use of appropriate airway adjuncts, using two-person technique whenever possible), use of a transport ventilator to free up hands (**Fig. 30.6**), and assigning a senior person to perform or supervise this critical skill.[10] When difficulty is encountered with achieving an adequate mask seal, such as copious blood/secretions, trauma, obesity, or facial hair, consider bypassing these anatomic difficulties with an EGD. EMS providers that are forced to provide one-person BMV without the benefit of a ventilator might also consider use of the NuMask, which demonstrated an advantage in one small cadaver study among EMS providers performing one-person BMV.[11]

Figure 30.6: Use of a simple transport ventilator to free up hands so that one provider may use both hands to achieve an optimal mask seal.

Noninvasive Positive Pressure Ventilation

One of the most important advances in EMS has been the widespread adoption of noninvasive positive pressure ventilation (NIPPV), also discussed in Chapters 9 and 32. In some jurisdictions, this procedure has been extended to the emergency medical technicians (EMT) level. Devices to provide continuous positive airway pressure (CPAP) are far more common than bi-level positive airway pressure (BPAP), but both are now available for the prehospital setting. These range from single-use devices to complex ventilators. NIPPV is most used as a bridge to facilitate transport to the hospital when other options such as medication-facilitated airway management (MFAM) are not in scope of practice or deemed too risky. In systems where MFAM is available, NIPPV is also used as a preoxygenation strategy and as an alternative to intubation in patients with predicted intubation difficulty, predicted need for only short-term positive pressure while other therapies have an effect, or those patients in need of ventilatory support but with a "Do Not Intubate" order.[12] As noted in Chapter 31, we believe that NIPPV can be safely deployed in selected patients with altered

mental status (AMS) as long as crews are able to maintain one-on-one monitoring at all times for any sign of vomiting.

The greatest barrier to applying CPAP in the prehospital setting is having to coach a hypoxemic, hypercarbic, and anxious patient in a loud and chaotic environment to wear the requisite tight-fitting mask. It is important for the provider to display gentle persistence and a calm, confident demeanor, even if they have little experience with the procedure. It is helpful to make eye contact and tell the patient, “This will help you breathe” while having them help hold the mask on their face until they can feel the benefit. Ideally, one provider will be dedicated to coaching the patient through the first several minutes of use. The person chosen for this “coaching” task does not have to be the most experienced airway manager, but they must be able to work effectively with the patient.[13,14]

Another unique prehospital challenge in the use of NIPPV is the availability of sufficient oxygen and compressed gases. There is wide variability among commercially available NIPPV devices related to oxygen consumption. Some devices can rapidly deplete oxygen reserves, especially when minute ventilation is high or mask seal is poor. When transport time is more than 10 to 15 minutes, crews should calculate consumption and supply as per the discussion further on.

Endotracheal Intubation

General intubation techniques, as well as preoxygenation, are covered extensively elsewhere in this text. The decision-making process surrounding intubation in the prehospital setting is discussed separately in Chapter 29. First and foremost, when access is limited or patients cannot be optimally positioned, responders should have a low threshold for use of an EGD, at least until the patient is moved to a better position or location.[15,16]

A frequently discussed scenario, unique to the prehospital environment, involves the seated but entrapped patient (eg, entrapped driver in a vehicle) requiring invasive airway management. When intubation is clearly preferred for such patients, a common approach is face-to-face laryngoscopy (**Fig. 30.7**). The technique can be very frustrating because of the unusual geometry of holding the blade upside down in the opposite hand while trying to sweep the tongue and perform the required finesse

movements, all in unusual and unfamiliar conditions. Multiple studies have demonstrated a significant advantage to video or optical laryngoscopy when a face-to-face intubation is required.[17-19] Another option, when access above the patient is available, is for the intubator to stand behind and over the patient, allowing space to lean over and perform laryngoscopy in a more familiar orientation (**Fig. 30.8**).

Figure 30.7: This photo demonstrates video laryngoscopy with the intubator positioned in front of, or face-to-face with, the entrapped patient.

Figure 30.8: This photo demonstrates video laryngoscopy with the intubator positioned behind and above the entrapped patient.

There are numerous positioning options for intubating a patient that is supine on the floor/ground, including sitting, straddling, kneeling, lying prone, and lying left lateral (**Figs. 30.9A-C**). Our recommendation, as discussed previously, is to reposition the patient prior to intubation rather than attempting the procedure with the patient supine, when possible. Several tips for proper positioning and achieving a ramped position for obese patients are discussed above.

Figures 30.9A-C: These photos demonstrate the left-lateral, prone, and kneeling positions for intubating a supine patient on the ground or floor. Note that the prone and left-lateral positions are more difficult when the patient is placed in a sniffing or ramped position.

If the posterior cartilages cannot be visualized on the initial attempt—despite external laryngeal manipulation and the jaw thrust maneuver—and great force is required to maintain the view, intubation will be difficult or impossible. An option in this situation, especially when the intubator has

limited upper arm strength, is a two-person approach (**Fig. 30.10**). In this maneuver, a trained assistant reaches over the patient from an inferior position of mechanical advantage and carefully takes control of the laryngoscope handle from the primary intubator with two hands. The primary intubator can then direct minor blade movements, if necessary, although in our experience this optimizes the view enough that this is not usually required.

Figure 30.10: Two-person direct laryngoscopy with an assistant providing lift along the axis of the handle from a position of mechanical advantage (after the intubator has appropriately placed the blade) while the intubator provides ongoing direction and passes the tube.

Intubation in direct sunlight or bright ambient light can be very difficult, particularly with video technology. If intubation must be attempted in these conditions, the intubator may consider placing a blanket over themselves and patient's head or enlist other personnel to provide shade with their bodies or clothing such as a turn-out coat (**Fig. 30.11**). Airway management in aircraft can present other challenges depending on configuration. **Figure 30.12** demonstrates simulated video laryngoscopy (VL) with the Intubrite system in an Augusta AW119 helicopter.

Figure 30.11: A provider uses a turn-out coat to provide shade during laryngoscopy to prevent bright light from affecting the view in the mouth or of the video screen.

Figure 30.12: Simulated video laryngoscopy with the Intubrite system in an Augusta AW119 helicopter.

Because patients undergoing emergency airway management are at high risk for regurgitation and aspiration, it is important to have suction equipment immediately available and utilize the SALAD technique described in Chapter 41. This is another reason why it is often preferable to manage the patient in the ambulance, aircraft, or hospital. Additionally, since most portable suctions do not have the capacity to manage massive emesis, consider having two units available and always be prepared to roll the patient.

VIDEO LARYNGOSCOPY

The first video laryngoscope was commercially available to the hospital market in 2001.[20] Since then, video laryngoscopy (VL) has become the mainstay of airway management both inside the hospital and in EMS. Video laryngoscopes are widely available to EMS and are recommended as a best practice for clinical care.[21]

The primary benefit of VL over traditional direct laryngoscopy (DL) is enhanced first-pass success. VL may improve glottic view by 1 Cormack-Lehane grade.[22] Novice intubators perform better utilizing VL over DL because intubation procedures per paramedic may be fewer per year compared to their emergency physician colleagues. An observational study of 517 patients in a high-performing EMS system reported statistically significant improvement in first-pass success rate when VL was utilized.[23] Lessons learned during the COVID-19 pandemic demonstrate that VL may outperform DL in terms of first-pass success rate and speed of endotracheal tube placement by paramedics while wearing full personal protective equipment.[24] Another advantage of VL over traditional DL is that it enables supervising staff to observe the glottic opening at the same time as the laryngoscopist. This may facilitate training and allows for another provider to confirm tracheal placement.[20]

Multiple video laryngoscope systems are available, as discussed in Chapter 16. Devices for prehospital use may be categorized according to blade geometry (standard, hyperangulated, straight) and by the presence or absence of a channel. Some devices may have multiple choices of blades and others just one or two sizes of a single geometry. Devices also vary by whether or not there is a cord to a separate monitor or an integrated monitor mounted on the handle. Most EMS systems prefer disposable blades or blade covers to avoid complicated cleaning requirements. Examples of more common devices in EMS include the McGrath Mac (**Fig. 30.13**) and the King Vision (**Fig. 30.14**). There is insufficient evidence to recommend one VL device over another, but all devices require consistent training. There may be strategic advantages to carrying a combination of standard geometry and hyperangulated blade designs for adults, or hyperangulated and straight blades for pediatrics, to accommodate varying anatomic challenges. However, this imposes additional costs and training requirements for a low-volume procedure.

Figure 30.13: McGrath video laryngoscope system. (©2022 Medtronic. All rights reserved. Used with the permission of Medtronic.)

Figure 30.14: King vision video laryngoscope. (Copyright © 2022 Ambu Inc.)

When available, VL should be the primary device for performing prehospital endotracheal intubation. There are essentially no absolute contraindications to performing VL during a medical emergency. Relative contraindications include blood, vomitus, or foreign body obstruction in the airway.[25] Even when substantial secretions are blocking an optimal view of the airway, the development of special techniques such as the suction-assisted laryngoscopy and airway decontamination method discussed in Chapter 41 enables providers to continue using VL despite heavy soiling of the airway.[26]

VERIFICATION OF AIRWAY MANAGEMENT PROCEDURES

It is imperative that all invasive airway procedures be confirmed objectively, as discussed in Chapter 20. $ETCO_2$ is the primary objective means of confirmation. There have been several studies demonstrating

unacceptable rates of missed esophageal prehospital intubations, especially in EMS systems not using capnometry or capnography.[27] All EMS systems should have this technology available, but just because it is available it does not mean it always gets used. If $ETCO_2$ is not detected, assume the tube is not in the airway, even during cardiac arrest. When in doubt, pull the device out and go back to BMV. On the contrary, when saturations are slow to improve, or are dropping but capnography reveals a normal waveform, trust the tube and look for other causes of hypoxemia.

There may be situations when capnography is unavailable or not functioning and the tube must be confirmed by other objective means. The most readily available alternative is by using a bougie, which can be placed down an established endotracheal tube to assess for palpable tracheal rings or "hold up" at the smaller airways.[28] Another alternative is an esophageal detector device, which uses suction to assess tube location by knowing that a noncollapsible trachea would allow air to quickly be drawn back up into an inflatable bulb or syringe, but a collapsible esophagus would prevent or only allow air to slowly come back. Chest radiography to determine tube depth is not viable in the prehospital setting. Critical care transport teams may perform intubations in small health care facilities where chest radiography is available but delayed, especially after hours. We do not believe that obtaining a chest x-ray is required prior to transport.

MEDICATION-FACILITATED AIRWAY MANAGEMENT (MFAM)

MFAM is discussed at length in Chapter 20. The controversy surrounding MFAM in the prehospital setting is discussed in Chapter 32. This is a complex procedure and is performed in very sick or injured patients. Even under the most controlled circumstance, there are real risks. When performed under less-than-ideal conditions, the potential for adverse events goes up significantly. Those agencies that perform prehospital MFAM need to be training constantly and consistently to stay proficient. Teams should also look for system-level solutions to increase operator efficiency and mitigate risk. Some examples include the use of carefully labeled and standardized syringes for different classes of medications and bags that organize all supplies (see **Fig. 30.15**).[29,30]

Figure 30.15: SCRAM adult emergency airway bag in use during simulated RSI. (Copyright © 2022 Ambu Inc.)

Because MFAM is a team effort, and there may be only one or two critical care providers on scene, it is necessary to train the first responding personnel in advance as assistants. In fact, this is a major component of the First Airway "Fundamentals of Airway Management" course for Basic Life Support (BLS) and Intermediate Life Support (ILS) providers. These providers may be trained to assist with external laryngeal manipulation, in-line cervical spine stabilization with jaw thrust, passing tubes over a bougie, and monitoring saturations. It is also helpful to train first responders to provide advanced life support (ALS) providers with the estimated patient weight prior to their arrival because this allows medications to be drawn up and the ventilator prepared. Because the most common patient to undergo MFAM in most prehospital agencies is the adult male with trauma, the ventilator can be set up at the beginning of the shift for this hypothetical patient to minimize the need for adjustments. Having all other airway equipment checked and ready in a familiar location also improves efficiency during high-stakes situations.

The actual performance of MFAM by EMS professionals should be similar to what is presented in Chapter 20, although there are unique

considerations in the prehospital environment. Let's consider these in the context of the 7 P's:

Preparation

There is often less space to carefully lay out airway supplies or to have them available ahead of time. For example, a flight crew might jump into the back of an ambulance to perform an MFAM procedure before transport and need to bring most supplies with them from the aircraft. Therefore, prehospital professionals usually keep most MFAM supplies in one bag (**Fig. 30.16**), although medications are likely kept separate. Steps that can be done ahead of time include calculation and preparation of medications and ventilator setup. Training first responders to provide information about the likely need for airway intervention as well as patient weight can be very helpful in this regard. Checklists are strongly encouraged. One additional step that may be unique to the prehospital environment is the need to clearly assign tasks and set expectations for that role. For example, it is possible that a first responder has never held in-line stabilization for a trauma intubation or assisted with external laryngeal manipulation.

Figure 30.16: pNeuton transport ventilator. (Courtesy of the Airon Corporation.)

Preoxygenation

Preoxygenation should, ideally, look the same in any setting except that prehospital professionals often have time constraints. If a patient clearly needs an invasive airway prior to transport yet is found with an oxygen saturation of 70%, some realistic compromises will need to be made, especially if there are injuries that need to be urgently addressed or major roadways that have been shut down. This could mean settling for 85% instead of 95% or perhaps choosing an alternative strategy such as rapid sequence airway (RSA) or delayed sequence intubation (DSI). Oxygen supplies may also be limited, as discussed later, necessitating modifications such as titration of oxygen in lieu of flush rate or waiting to start apneic nasal oxygen until just before intubation. NIPPV or careful mask ventilation should always be considered, especially when saturation is less than 93%.

Physiologic Optimization

Much like preoxygenation, time constraints may lead to realistic compromises, but there are also cases where physiology is so poor and the time necessary to stabilize is just too great to justify staying on the scene. In these cases, it may be reasonable to initiate transport with ongoing resuscitation and either defer invasive airway management to the receiving hospital or perform MFAM under less-than-ideal conditions during transport. This is a complex risk–benefit calculation that requires a great deal of practice and experience. The providers also need the confidence and support of medical direction/leadership to justify these decisions to the receiving teams who often do not understand the prehospital environment or might even have less sophisticated approaches to MFAM in general.

Paralysis With Induction

The rationale for medication choices is the same in the prehospital environment as in the hospital setting, although there may be fewer options out of practicality. Etomidate is a solid choice and appropriate for all situations. Ketamine is a reasonable alternative. Rocuronium is an ideal choice for neuromuscular blockade because it avoids the need to consider the potential contraindications that accompany succinylcholine. The longer duration of action helps to get the patient stabilized on the ventilator. Antiquated arguments against rocuronium have been centered on the

misguided notion that in the event of a failed airway a patient that had received shorter-acting succinylcholine could be awakened. Patients that require prehospital MFAM are simply too sick to be “awakened,” and by the time even succinylcholine has worn off, the providers have usually moved on appropriately to plan B or plan C.

Positioning

Optimal positioning is equally important in the prehospital environment, although it may take more creativity, as discussed previously. The major positioning activities should generally be done before preoxygenation. This step refers to the final positioning undertaken once medications have taken effect.

Placement With Proof

The basic mechanics of laryngoscopy and tube delivery are the same in any environment and are discussed extensively in other chapters. We recommend using continuous waveform capnography for both the initial confirmation and subsequent monitoring; this provides much more information than qualitative colorometric devices.

Post-Intubation Management

In general, these steps are the same as in the hospital with extra attention to securing endotracheal tubes and EGDs well enough to prevent accidental dislodgement with transport.

In general, care of the intubated patient in the field should mirror care in the hospital. After initial confirmation, the priority in prehospital care is preventing the invasive airway device from being accidentally or inadvertently dislodged. The EGDs are more forgiving than an ET tube or cricothyrotomy, but even these devices should be carefully secured using appropriate equipment. Methods used to achieve this are the same in the prehospital and hospital settings. One additional consideration in the field is the use of a cervical collar in medical patients, particularly in pediatrics, to prevent head rotation and subsequent tube movement. Although this has been very popular in some jurisdictions, the competing concern is potential

impairment of cerebral blood flow.[31] Another issue is that the patient will undergo unnecessary imaging procedures because the “message” will get lost in multiple patient hand-offs and subsequent providers may assume that a cervical injury must have been suspected. On balance, we do not routinely recommend this technique in adult patients and prefer securing the device well in the mouth.

Patients should be continuously monitored, including capnography. Medication options for analgesia, sedation analgesia, and hemodynamics are similar to those in hospital settings. Infusions are always desirable when time and equipment permit, although intermittent boluses are acceptable. Gastric tubes are often overlooked or deferred but should be placed when possible. Second-generation EGDs have a channel to facilitate gastric tube placement, but it is imperative to stock the sizes of gastric tube that will fit through the channel.

There is high-quality evidence that overventilation is harmful to many patients, regardless of the type of advanced airway placed.[32] The optimal way to prevent overventilation is with the use of a mechanical ventilator. We recommend that ventilators always be used in the setting of MFAM, whether an endotracheal tube or EGDs were inserted. Ventilator initiation may sometimes be delayed until moving a patient into the helicopter, but there still needs to be careful attention to appropriate tidal volume and rate for the size of the patient, their condition, and capnography values. Ventilators may also be used for mask ventilation and during cardiac arrest management. Numerous devices are now available for prehospital use and these range from simple devices that allow only for adjustment of rate and volume to complex critical care transport devices that are nearly as sophisticated as intensive care unit (ICU) ventilators. Many of these ventilators will also allow for the titration of oxygen concentration, which helps to both maintain supplies and avoid hyperoxia.

Simple ventilators (ParaPac, pNeuton, CAREvent, AutoVent) generally provide volume modes of ventilation with adjustable rate, volume, and positive end-expiratory pressures (PEEP) (**Figs. 30.17-30.19**). Some also allow for variable oxygen delivery (usually 50% or 100%). More sophisticated transport ventilators such as the ReVel or LTV provide pressure and volume modes as well as the ability to sense and synchronize ventilation. These ventilators will match most common ventilation modes

for hospitalized adult and pediatric patients. The most sophisticated ventilators, such as the HAMILTON-T1 (**Fig. 30.20**), will even allow for airway pressure release ventilation (APRV), BPAP, and high-flow nasal cannula (HFNC).

Figure 30.17: paraPAC transport ventilator. (Courtesy of ICU Medical.)

Figure 30.18: CAREvent transport ventilator. (eSeries Transport Ventilators © 2016 O-Two Medical Technologies Inc. All Rights Reserved.)

Figure 30.19: AUTOVENT 4000 transport ventilator. (Courtesy of Allied Healthcare Products, Inc.)

Figure 30.20: HAMILTON-T1 Ventilator. (© Hamilton Medical. All rights reserved.)

The Oxylator (CPR Medical Devices, Inc, Ontario, Canada) is described as a combination between a bag-valve mask and a portable ventilator (**Fig. 30.21**). It is oxygen powered and acts as a reusable pressure-controlled ventilator to be attached to a face mask, extraglottic airway, or endotracheal tube. The device delivers a preset pressure (settings 20-45 cm H_2O) in either an automatic or a manual mode. In automatic mode, the target minute ventilation is 10 to 12 L/min. When increased pressure occurs, the device both cuts off flow and alarms and chatters to alert the operator to adjust. In the case of mask ventilation, this is usually an excellent indicator that the airway needs to be repositioned. Depending on the model, the oxygen consumption is 30 to 40 L/min, but the usual flow to the patient is 15 to 30 L/min; either way this may consume substantial oxygen supplies and overventilate some patients unless manual mode is used and ventilation titrated to end-tidal CO_2. The device will deliver only 100% oxygen (unless a spontaneously breathing patient has a minute ventilation >30 L/min and entrains air) and just 2 to 4 cm H_2O of PEEP unless a PEEP valve is added. This is reasonable during cardiac arrest resuscitation but may not be ideal on return of spontaneous circulation (ROSC). Limited operating room and animal studies demonstrate effectiveness and superior ventilation by first responders compared to BMV.

Figure 30.21: Photo of Oxylators in use during hoist operation in Germany. (Courtesy of Jan Grundgeiger and Markus Bitsche.)

TRANSPORT CONSIDERATIONS

Positioning

Transport of “airway patients” falls into two categories: those that have already secured airways and those that have not. When possible, the secured group should be positioned with at least 20° of head elevation to prevent aspiration, although data to support this is limited. Likewise, inserting a gastric tube and placing it to suction is common practice and, intuitively, should help prevent aspiration, but these data are also lacking.

The latter category is more complicated and is further divided into three major subgroups: (i) those primarily with AMS, (ii) those primarily with upper airway issues, and (iii) those with lower airway issues. In general, it is wise to secure an airway prior to transport whenever there is concern for potential deterioration before arrival at the destination hospital; however all patients present on a spectrum, and there are circumstances where one weighs the risks and benefits and may elect to defer, as discussed in Chapters 29 and 31.

In patients with AMS but an unsecured airway, there is a trade-off between positioning laterally to decrease the risk of aspiration and being ideally positioned for airway management in case that becomes necessary because there may not be enough hands and/or space to reposition quickly. Unfortunately, many air medical aircraft do not allow for intubation when a patient is in an optimal ramped position. These are further reasons to consider airway management prior to transport.

Patients with upper airway issues should be positioned to allow them to maintain an open airway and drain secretions. Use a seated, upright position if the transport platform allows it. These patients typically have predictors of difficulty, so transport without a secure airway should be undertaken only by experienced personnel or when there are no other options. A classic dilemma is the patient with significant facial trauma who may be safe for transport when seated but would require intubation to lie flat. It may be better to spend more time taking such a patient by ground if that allows safer positioning and access. Patients with lower airway issues such as asthma should be positioned to maximize respiratory function.

Packaging for Transport

Critically ill or injured patients are often a tangle of wires and tubes, and they are often wrapped in specialized blankets for environmental protection. Ensure invasive airways are secure before any movement. The ventilator needs to be accessible and the monitors, especially saturation and capnography, easily visible. At least one IV site needs to be available for emergency medication delivery. Keep a bag and mask device and an EGD readily available in the event of tube dislodgement or ventilator failure.

OXYGEN CONSUMPTION/TANK FACTORS

In the hospital setting, outside of a pandemic disaster, oxygen is never in short supply, so this does not factor into clinical decisions. In the prehospital environment, on the other hand, oxygen supplies are usually limited. For example, it may be routine to use flush rate oxygen and early placement of a nasal cannula at 15 L/min in every adult patient undergoing rapid sequence intubation (RSI) in the hospital, but this might deplete the supplies in an ambulance, especially if transport is long. In these situations, it is prudent to use just enough oxygen to maintain the desired level of oxygenation, and flow through the nasal cannula might not be started until the moment the nonrebreather mask is removed to initiate laryngoscopy.

Oxygen consumption is a major factor in the choice of modality to support the patient as well. Providers should be very familiar with the oxygen consumption formula and the factor for any tank sizes utilized.

Minutes available = Tank Factor × (Remaining PSI – reserve)/Flow in L/min

Although it may be medically ideal to avoid intubation in certain clinical conditions, this may preclude safe transfer to a specialty center. Humidified HFNC is the greatest consumer of oxygen. Sixty liters per minute of flow at 100% FIO_2 will consume all the oxygen in a full large M tank in 40 minutes. Switching this same patient to CPAP or BPAP—assuming a tight-fitting mask—might allow the same oxygenation with much less flow owing to greater PEEP and more efficient movement of gas into the patient. Intubating the patient may further reduce the total oxygen consumption.

Oxygen consumption with NIPPV also varies greatly based on the FIO_2 and the delivery system. There are a variety of systems available for

prehospital use. NIPPV delivery via an electrically powered ventilator is usually the most efficient and titratable but is not always available. The popular, disposable, oxygen-powered O_2-MAX from Pulmodyne consumes a full D tank in less than 10 minutes at 90% FIO_2. This may be a reasonable approach if using the CPAP to preoxygenate for MFAM but would not be sustainable by itself for most transports unless the FIO_2 could be titrated down.

TIPS AND PEARLS

- Move patients to a controlled environment and stretcher prior to airway management whenever possible.
- Record and download continuous vital signs from airway procedures for quality improvement.
  Use the head of the bed, blankets, or whatever is available to achieve a sniffing or ramped position.
- Have an experienced person perform or supervise BMV rather than delegating to the most junior provider, and consider moving early to an EGD in the event of difficulty in achieving a mask seal with two providers.
- Display gentle persistence and a calm and confident manner when coaching a patient to tolerate CPAP. Consider having them hold the mask themselves.
- It may be appropriate to utilize CPAP in selected cases of AMS with close one-on-one monitoring.
- Train providers in advance to assist with external laryngeal manipulation, in-line cervical spine stabilization with jaw thrust, passing tubes over a bougie, and monitoring saturations.
- All invasive airways should be confirmed objectively—usually with $ETCO_2$. When the $ETCO_2$ cannot be detected or drops precipitously, pull the device and resume BMV.
- In general, it is wise to secure an airway prior to transport whenever there is concern for potential deterioration before arrival at the destination hospital, but in some cases it may be reasonable to initiate

transport with ongoing resuscitation and defer invasive airway management until hospital arrival.

- The optimal way to prevent inconsistent or overventilation is by using a mechanical ventilator. We recommend that ventilators always be used in the setting of MFAM.
- Oxygen consumption is a major factor in the choice of modality during transport. Providers should be familiar with the oxygen consumption formula and the factor for any tank sizes utilized.
- When available, VL should be the primary method to perform prehospital endotracheal intubation.

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CHAPTER 31

Difficult and Failed Airway Management in EMS

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THE PREHOSPITAL CHALLENGE

Airway management in the prehospital setting creates unique situations not experienced by clinical staff working in-hospital. The emergency medical services (EMS) environment can be unforgiving on clinicians and patients alike. EMS providers are often without additional backup readily available. Some of the unique challenges present in the prehospital environment include noise, bright sunlight or darkness, temperature extremes, patient access issues, austere and uncontrolled environments, and hurdles related to patient positioning. Taken in sum, airway management in the prehospital setting should always be treated as difficult. However, it is imperative that systematic, careful, and purposeful evaluation for specific features predicting difficulty always be attempted to mitigate any readily correctable barrier to successful airway management. Further, as a function of these assessments, the clinician should make an informed decision about how to manage the patient's airway. Experience would suggest that errors in prehospital medication-facilitated airway management (MFAM) are more often errors in decision making and in failing to predict difficulty than errors in performance of technical skills.

PREDICTION OF THE DIFFICULT AIRWAY IN THE PREHOSPITAL SETTING

Traditionally, we have defined difficulty in airway management largely as a function of what anatomic variables are present that may hinder access to the airway. The mnemonics used to recall these attributes are LEMON, ROMAN, RODS, and SMART (discussed in Chapter 2). These prediction criteria refer to anatomically difficult intubation, bag-mask ventilation (BMV), extraglottic airway device (EGD) placement, and cricothyroidotomy, respectively. For the most part, these airway assessment tools apply equally well in the prehospital setting as in the hospital setting. In EMS, however, we advise broadening the LEMON mnemonic to become "LEMONS," with the "S" standing for "Sat's and Situation." Situational factors to consider include immediate hazards, personnel, equipment, resource limitations, environmental considerations, limitations in patient access, patient positioning, planned mode of transportation, and transport time. For example, an edentulous thin patient with no anatomic predictors of difficulty may become very difficult to manage when trapped in a vehicle at night with an ambient temperature of –5°F and snow. Low oxygen saturation indicates a lack of oxygen reserve and safe apnea time, which limits the amount of time available for a safe intubation attempt.

Recently, there has been much more focus on the critical physiologic factors that can lead to patient harm if not addressed prior to advanced airway management in any environment. These include hypotension, hypoxemia, volume deficiency, acidosis, right heart failure, and a hyperdynamic state with increased oxygen consumption, all of which can be remembered using the CRASH mnemonic, as discussed in Chapter 3.

THE PREHOSPITAL CONUNDRUM

Although basic airway measures should never wait, prehospital providers have the unique option to defer definitive airway management until arrival at an emergency department (ED), so long as effective oxygenation and ventilation can be accomplished by any other means. Therefore, the question of "is this patient better served by airway management now versus delaying until arrival at the hospital" must be considered in addition to the traditional indications for intubation/timing consideration. In some cases, the margin of safety may be increased by transporting to an appropriate hospital facility before advanced airway maneuvers (eg, rapid sequence

intubation [RSI]) are employed. In others, such as inhalation injury or anaphylaxis, patients may have better outcomes if managed early, when they have more reserve or before their disease process progresses. Given these factors, the decision to embark on invasive airway management is complex and must be taken case by case, with a strong focus on assessing predictors of difficulty, as well as the physiologic status of each patient. It is also as important to weigh one's personal skill level as a potential benefit or hindrance in each case.

WHEN IS IT BETTER TO WAIT?

Although this question should be asked with every emergency airway encounter, it is particularly important in the prehospital setting. Consider the following two cases, each with an anticipated 15-minute transport time to an appropriate receiving facility:

- A 40-year-old, 80-kg man with sudden collapse, new left hemiparesis, Glasgow Coma Scale of 6, marked hypertension, no swallowing reflex, but normal respiratory pattern with O_2 saturations of 99% and a nasal end-tidal CO_2 of 40.
- A 40-year-old, 80-kg man extricated from a house fire, with worsening stridor, and evidence of upper airway burns. O_2 saturations of 93% on nonrebreather mask and progressively becoming more agitated.

Both patients have clear indications for securing the airway, although the decision process for the prehospital airway manager, particularly with respect to urgency, should be quite different. In the first case, if the patient is not deteriorating further, assessment of costs and potential benefits suggest that it would be best to defer intubation to the ED. This would provide for a more controlled RSI with additional backup resources. In this case, the patient's oxygenation and ventilation status is adequate. Although this patient is clearly at risk for aspiration, the benefit of rapid transport to a facility where treatment for potential stroke can begin immediately likely outweighs the risk of aspiration. Careful management of the airway with positioning, suctioning, and BMV (as indicated) will likely be sufficient to provide the necessary oxygenation. As evidenced by this example, training

must emphasize that having the ability to perform a procedure does not always equate to the need to perform the procedure.

In the second case, assessment of potential risks versus benefits suggests that it would be best *not* to defer intubation to the ED. Even a brief delay, such as a 15-minute transport, allows time for further deterioration and airway swelling, increasing the threat to the patient and making intubation progressively more difficult. Also, the patient's agitation may make transport unsafe for the patient and EMS providers. If the provider is authorized to perform MFAM, the decision to intubate now can certainly be justified.

APPLYING THE EMS AIRWAY ALGORITHM FOR MFAM PRACTITIONERS

The EMS airway algorithm is modeled after the universal and difficult airway algorithms presented at the outset of this text. The spirit is the same, but the EMS algorithm is unique to respect specific prehospital considerations: the need to consider transport times, local protocols, medical direction, and other factors (**Fig. 31.1**). The algorithm is intended to be used by MFAM practitioners after initial assessment and Basic Life Support (BLS) airway maneuvers. If an indication for invasive airway management is present, then the EMS airway algorithm can be employed to help determine the optimal strategy.

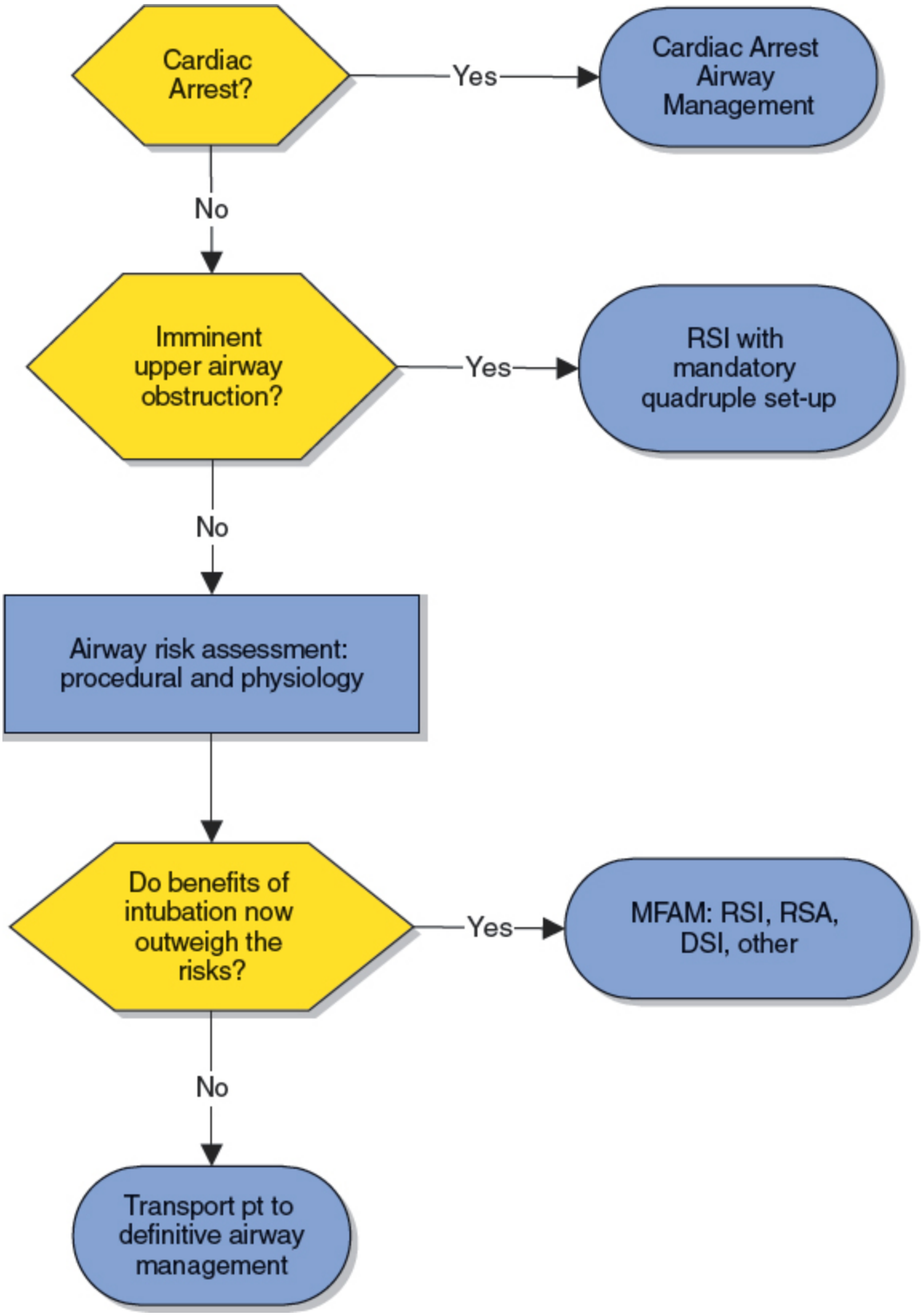
Cardiac Arrest?
Yes
Cardiac Arrest Airway Management
No
Imminent upper airway obstruction?
Yes
RSI with mandatory quadruple set-up
No
Airway risk assessment: procedural and physiology
Do benefits of intubation now outweigh the risks?
Yes
MFAM: RSI, RSA, DSI, other
No
Transport pt to definitive airway management

Figure 31.1: The EMS difficult airway algorithm. DSI, delayed sequence intubation; MFAM, medication-facilitated airway management; RSA, rapid sequence airway; RSI, rapid sequence intubation.

The first step is to determine whether this is a cardiac arrest situation. If so, local protocols for cardiac arrest airway management should be followed. These will likely include emphasis on high-quality cardiopulmonary resuscitation (CPR) and BLS airway maneuvers but not necessarily intubation. In fact, many high-performing EMS systems throughout the world have moved exclusively to BMV and extraglottic airways for cardiac arrest situation. This is discussed further in Chapter 32.

If the patient is not in cardiac arrest, the next step is to determine whether you will lose any chance of securing an airway through the pharynx because of something causing very rapid impending airway closure (see Chapters 1 and 5). In this rare "forced to act" situation, we suggest immediate RSI with mandatory quadruple setup (ready for intubation, optimal BMV, EGD rescue, and cricothyrotomy), regardless of any high-risk difficult airway features. Although RSI could lead to a fatal ventilation failure if the procedure is unsuccessful, the risk of not doing so in this situation is more likely a fatal outcome. An EGD may temporize the situation, but since this type of airway occlusion often occurs distal to the outlet of the EGD, or impedes EGD placement, cricothyrotomy would usually be the preferred alternate/rescue strategy. For this same reason, rapid sequence airway (RSA) is not recommended in this scenario.

In most airway encounters, you will not confront such a "forced to act" situation and can proceed to a complete airway assessment. The LEMONS, ROMAN, RODS, and SMART mnemonics are used as aids when considering anatomic procedural difficulty. The CRASH mnemonic may be employed as an aid to consider the risk of physiologic deterioration. Keeping all this in mind, a risk/benefit calculation should be made: do the benefits of intubation now outweigh the risks (in contrast to rapid transport to the receiving facility)? Factors weighed could include nonprecipitous airway swelling that could progress over a long transport, prolonged transport in and of itself (eg, >30 minutes), or patients at high risk for aspiration (eg, very decreased level of consciousness, active airway bleeding, or vomiting). If none of these factors are present, it is usually advisable to defer invasive airway management, and continue the BLS

measures that are maintaining adequate saturations, and transport to an appropriate facility. On the other hand, if one or more of these factors is present, intubation may now be prudent. It is incumbent on prehospital providers and medical directors to ensure adequate preparation for and quality assurance review of these decisions.

Critical to this decision making is prediction of whether BMV or an EGD is able to rescue peri-intubation desaturation events. When multiple ROMAN or RODS attributes are present, RSI or RSA is not recommended. The “hospital-based” Difficult Airway Algorithm would recommend “awake techniques” in such cases. Unfortunately, outside of blind nasal intubation, awake techniques are not available to prehospital airway managers. If an awake technique is neither available nor appropriate, then transport with BLS and close monitoring may be what is best for that patient. As a last resort, RSI or RSA with full front of neck access preparation may be an option if an invasive airway is strongly felt to be in that patient’s best interest. Again, it is incumbent on prehospital providers, as well as medical directors, to ensure adequate preparation for and review of these decisions.

When possible, it is recommended to have at least two experienced operators present. The additional operator should serve as a “second opinion” for checks and balances to make sure the decision to proceed is valid. He or she may then assist the primary airway manager with medication administration, vital signs monitoring, external laryngeal manipulation (ELM), jaw thrust, and bougie use. The second operator should also be focused on preparations for peri-intubation desaturation and hypotension. In cases where significant difficulty is predicted, a quadruple setup is recommended. When hypotension is present or anticipated, vasopressors and inotropes should be infusing or readily available. The second airway provider may also be extremely helpful in maintaining overall situational awareness, because the primary operator will likely become task focused when the procedure begins. The use of an airway checklist is highly recommended.

In the event of an unsuccessful intubation attempt, it is important to determine whether the miss was related to an anatomic issue impeding visualization or an abrupt change in physiologic parameters (eg, precipitous decline in oxygenation). In the former situation, try to ascertain what

happened on the first attempt and make appropriate corrective actions—it is rarely productive to repeat the exact same process. Consider using a bougie (with standard geometry laryngoscopy), repositioning the head and neck, employing ELM, changing device or blade size, or changing the operator. Local protocols will likely govern this process. In the latter situation where a drop in saturation below 93% forced an abort, perform optimal BMV and prepare to employ the emergency action steps described further on. If oxygenation can be corrected and the epiglottis was visualized initially, an additional attempt may be appropriate. If the epiglottis was never visualized, it may still be more appropriate to move to an EGD or cricothyrotomy (or provide BMV to the hospital).

In the prehospital setting, it is particularly important to focus on first-attempt success for patient safety. This may mean moving to an EGD or cricothyrotomy after only one unsuccessful intubation attempt. As a result of this imperative, combined with the infrequent performance of procedures and the unique challenges of the prehospital environment, unsuccessful intubation attempts should be considered inevitable despite optimal technique.

THE DIFFICULT AIRWAY FOR THE NON-MFAM PROVIDER

For the provider that does not have the option for MFAM, invasive airway management is most likely performed in cardiac arrest situations. Predicting difficulty in these situations is only modestly useful because some form of airway management must proceed regardless. BMV is usually the first mode of management, whether or not the ROMAN mnemonic has positive attributes. The prediction of difficulty might lower the threshold to move to an EGD or other invasive airway but does not determine whether you proceed at all. Likewise, if everything else has failed, a cricothyrotomy should be attempted even if the SMART mnemonic predicts difficulty.

Outside of cardiac arrest, invasive airway management without MFAM is limited to rare blind nasal intubations and surgical airways. Each clinician should assess the patient and determine whether immediate intubation or cricothyrotomy is required or whether the patient can be safely maintained with basic interventions until MFAM can be performed, either at the

hospital arrival or by requesting additional resources. A provider who can recognize the potential dangers of performing a skill and deferring it until it can be done under better conditions is a mature airway manager and patient advocate. It is always best to take the approach that we should be doing something *for* the patient and not something *to* the patient. Performing a blind nasal tracheal intubation on an obtunded stroke patient may be successful, but is it worth the risk of increasing ICP and possible aspiration? On the other hand, a patient with a major head and face injury who cannot be adequately oxygenated with BMV and has trismus that precludes an EGD or intubation needs an immediate cricothyrotomy if within scope of practice; waiting for MFAM is not an option.

RAPID OR CRITICAL OXYGEN DESATURATION

In the high stress, high cognitive load environment of prehospital care, we believe that the recommended steps to address rapid or critical desaturation should be direct and easy to remember. Therefore, we prefer a progression of "emergency action steps" (**Fig. 31.2**) to a "failed airway algorithm." These emergency action steps can be employed anytime rapid or critical desaturation (as defined by the provider in that specific patient context) occurs.

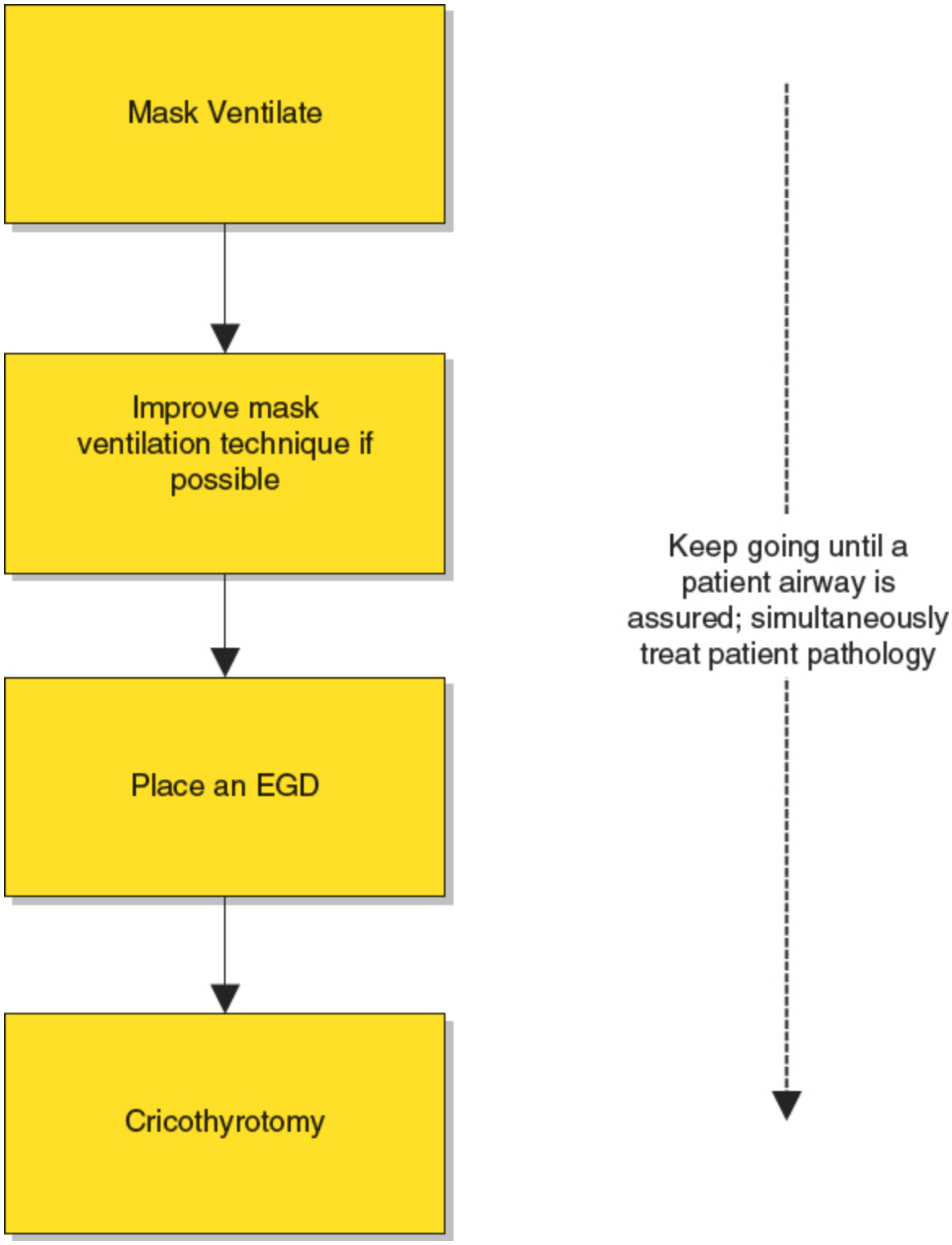

Figure 31.2: Emergency action steps.

- Step 1: **Cease any noncritical tasks**
- Step 2: **Optimal mask ventilation** (Chapter 12)

- Step 3: **Better mask ventilation** with PEEP and maximal oxygen
  - Assess ventilation with capnography, chest rise, air leak
  - Consider pneumothorax, PE, asthma, or COPD
- Step 4: **EGD**
  - These usually maintain oxygenation and ventilation until hospital arrival
- Step 5: **Cricothyrotomy**
  - Surgical cricothyrotomy is preferred.
  - Although cricothyrotomy in the field is and should be a rare event, providers must not be afraid to perform the procedure when indicated and should do so as soon as possible.

TIPS AND PEARLS

- Even under optimal conditions, all prehospital airways should be considered difficult, and contingency plans should be made in advance regarding the airway devices.
- Airway assessment mnemonics can help account for situational factors that arise in prehospital care.
- EMS providers must consider not only whether a patient needs invasive airway management but also whether that management may be safely deferred to the hospital. However, in situations of rapid airway deterioration or critical hypoxemia, crews should attempt to safely secure the airway prior to transport.
- In the prehospital environment, the use of two advanced airway providers for any medication-facilitated airway is recommended.
- Always consider the airway management plan in the context of the situation and the patient. It is impossible to have a “one-size-fits-all” approach.
- Do not hesitate to move to an EGD or cricothyroidotomy if oxygenation or ventilation cannot be maintained by other means.
- Avoid the use of neuromuscular blocking agents (NMBAs) or potent sedative agents unless you are confident you can provide effective gas

exchange with BLS measures and front of neck access is available. In other words, do not burn bridges.

- Because it is the oxygenation status that often distinguishes a failed attempt from a critical situation, it is crucial that the EMS airway manager focus on meticulous pre- and peri-intubation oxygenation strategies and be ready to employ optimal BMV as soon as an attempt is not successful.
- Slow down, take a methodical approach, and communicate. *Success lies with the team.* Planning even in cardiac arrest situations is vital. Use of checklists is recommended.

CHAPTER 32

Controversies in EMS Airway Management

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INTRODUCTION

Prehospital providers often need to manage airways before patients reach their final destination. This can occur in the field or prior to interfacility transport. Whereas many aspects of prehospital airway management are firmly entrenched, others continue to be topics of ongoing debate and investigation. This chapter focuses on current controversies in prehospital airway management and the available supporting evidence.

FRONT OF NECK ACCESS

This generic term describes an invasive surgical approach to definitive airway management that permits oxygenation and ventilation directly into the airway below the glottic opening when other procedures have failed or were bypassed owing to urgency and predicted difficulty.[1] In some settings, this might include a tracheostomy, but in emergency medical service (EMS) this refers exclusively to access through the cricothyroid membrane, that is, a cricothyrotomy. There are two primary variations of this procedure: surgical, also known as the open technique, and needle based, also referred to as minimally invasive techniques, which include any of the Seldinger-based approaches.

These are important yet very infrequent procedures in the prehospital setting. One UK EMS service responding to about 1.5 million calls per year

reported only one cricothyrotomy per month by their advanced paramedics.[2] The major areas of controversy are (a) the level of provider that should have this skill in scope of practice, (b) whether the technique should be surgical or needle based, and (c) whether pediatric options should be included.

Front of neck access (FONA) is usually restricted to paramedics, flight nurses, and physicians. There is no evidence or reason to believe that other providers could not perform these procedures safely if given sufficient training, but the challenge is having enough experience to recognize the appropriate indications for the procedure. It is generally advisable to focus less trained individuals on basic airway maneuvers. In military and tactical environments, it is reasonable to train emergency medical technicians (EMTs) or Combat Medics in these skills because the likelihood of encountering an indication is higher and other airway management options and resources are more limited.

For adult patients, the weight of the evidence supports open surgical cricothyrotomy over other techniques in terms of success rates, complications, and procedural time.[3] In-hospital care has largely abandoned Seldinger-style surgical access. The U.S. National Association of EMS Physicians now makes the same recommendation.[4] Despite this, there are many jurisdictions that continue to restrict surgical cricothyrotomy in prehospital practice by nonphysicians. The second-best option is a percutaneous approach that allows for placement of catheter either over a needle, using an integral dilator, or with the Seldinger technique. There is no consistent evidence that one percutaneous approach is better than another.[5-7] The least desirable approach in adults is a pure needle cricothyrotomy.

In children, variably defined as less than 8 to 12 years of age, the only option for FONA is a needle. Ventilation through a needle cricothyrotomy is best done with jet insufflation, but this is often not available. Pediatric needle cricothyrotomy is a rare prehospital procedure (47 procedures reported in 950 000 encounters), and there are few data available on success rates, complications, or outcomes.[8,9] It is likely that these procedures are performed late in resuscitations when a good outcome is already unlikely or in cases of distal foreign bodies, where any ventilation is likely to fail. For these reasons, some jurisdictions have elected not to maintain any means of

FONA in the scope of practice for prehospital providers and focus instead on basic life support (BLS) airway management and rapid transport.

AIRWAY STRATEGIES FOR OHCA

Out-of-hospital cardiac arrest (OHCA) is the most common indication for invasive airway management in many EMS systems. Endotracheal intubation (ETI) was the predominate strategy for many years. One of the first major trials to question this approach was the Canadian Ontario Prehospital Advanced Life Support (OPALS) trial. Current available evidence has suggested improved outcomes for OHCA patients managed with bag-mask ventilation (BMV) alone over intubation or extraglottic airways. These results may be confounded by patients that had early return of spontaneous circulation, a group of patients with an excellent chance of survival.[10] However, some researchers have even found improved outcomes for patients that had received BMV as a rescue technique after a failed invasive airway. We do not yet know if this reflects something inherently detrimental from invasive airways in OHCA or perhaps that they facilitate overventilation compared to BMV, which we know to influence poor outcomes.[11]

For now, the major research question in prehospital OHCA airway management remains the role of intubation versus extraglottic airways. Two recent, large, randomized controlled international trials have helped us to answer that question. A multicenter US project cluster randomized over three thousand patients in OHCA to airway management with either ET intubation or the King Laryngeal Tube (King-LT).[12] First-pass success was 51.6% with intubation and 90.3% for the King-LT. Survival at 72 hours and neurologic status at discharge were both improved in those patients managed with a King-LT. A multicenter research project in the UK cluster randomized almost 9300 patients with OHCA to airway management with either ETI or the i-gel. Airway management was successful within two attempts (first attempt not reported) for 79% of intubations and 87.4% of extraglottic devices (EGDs).[13] Favorable functional outcomes were not different between the two groups at 30 days. Interestingly, aspiration rates were not different between patients managed with an EGD or intubation in either of these trials, suggesting that many patients had aspirated prior to

airway management and/or that these EGDs provide comparable aspiration protection in OHCA.

Practice styles for airway management in OHCA remain highly variable. We believe that the current evidence supports BMV or EGD as the default strategy. It is still reasonable for agencies or jurisdictions to allow intubation for qualified providers, but education must focus on not interrupting compressions and moving early to an alternate strategy if intubation fails. Regardless of the airway strategy, it is critical to avoid overventilation.

MEDICATION-FACILITATED AIRWAY MANAGEMENT

MFAM, whether it be rapid sequence intubation (RSI), delayed sequence intubation (DSI), or rapid sequence airway (RSA), remains one of the most controversial areas in all of EMS owing to concerns about safety amid limited data to show improved patient outcomes (**Fig. 32.1**). Adding to this is a dramatic variation in protocols, terminology, medication choices, target patient populations, required initial and continuing education, and verification of procedural competency.[13] This wide variability not only generates confusion among providers and medical directors, but also likely limits fair comparison of airway management practices across agencies within multijurisdictional research studies.

Figure 32.1: Simulated prehospital medication-facilitated airway procedure with video laryngoscopy. Note the use of continuous waveform capnography and PEEP.

Although it is true that MFAM can improve the chances of first-pass success when placing an endotracheal tube (ETT) or EGD, it does not make an impossible airway possible.[14-17] Because MFAM is employed, by definition, in patients who are spontaneously breathing, the risk of taking away the patient's intrinsic respiratory drive and being unable to replace it is real.

The ratio of the risks associated with MFAM versus the rewards of improved patient outcomes is highly variable in the current literature. Initial prehospital RSI studies largely focused on the management of patients with moderate to severe traumatic brain injuries. A landmark article out of San Diego in 2003 initially demonstrated worse outcomes and increased mortality in patients undergoing prehospital RSI after sustaining a head injury, resulting in a Glasgow Coma Scale (GCS) score of 8 or less, compared to matched control subjects.[18] A subsequent analysis utilizing almost continuously recording pulse oximetry and capnography revealed desaturation in more than half of patients, many of whom had acceptable

saturations prior to the RSI.[19] Further analysis suggested that worse outcomes and increased mortality were strongly associated with hypocapnia resulting from hyperventilation and with profound (SpO_2 <70%) desaturation events.[20] Accordingly, patients cared for by prehospital teams capable of monitoring $EtCO_2$ and adjusting transport ventilator settings as needed appeared to have better outcomes.[21]

While the more recent development and implementation of a comprehensive clinical care bundle has been shown to decrease rates of adverse events such as peri-intubation hypoxia, the cost associated with maintaining such programs represents an enormous investment.[14,21] As such, not every EMS system will be able to implement, support, or sustain a quality MFAM program. The MFAM program should not be considered a requirement for any or all providers; some systems limit participation to physicians, senior paramedics, or special operations staff.[22-24] Systems that elect to include MFAM in their scope of practice must weigh the evidence as well as local factors such as transport times, procedural volumes, and success rates. Any system considering or employing prehospital MFAM by nonphysicians should have engaged and supportive medical oversight and a supportive local medical community, including anesthesiologists willing and able to provide opportunities for skill maintenance in the operating room. A robust initial training program that is adequate to ensure success, a continuous quality improvement process, including 100% chart review for every procedure, the maturity of prehospital clinicians to focus on ways to optimize first-pass success, and the commitment to utilize EGDs would represent best practice. In addition, a budget sufficient for continuous capnography, transport ventilators, and VL technology would make prehospital MFAM the safest for patients.

DELAYED SEQUENCE INTUBATION

DSI involves providing “procedural sedation” to facilitate the “procedure” of preoxygenation in a patient who is hypoxic, agitated, and unable to cooperate.[25,26] DSI has been described as slowly administering a dissociative dose of ketamine that is unlikely to negatively affect respiratory drive or airway reflexes but will allow for adequate preoxygenation with a face mask or noninvasive positive pressure ventilation (NIPPV).[25] Once

oxygenation improves, the sequence is resumed and a paralytic agent administered to facilitate intubation.[25] This technique was initially shown to be effective in a small (*n*=62) multicenter, prospective, observational study involving highly skilled airway managers in the hospital setting and should be undertaken with caution.[25] Published reports on the out-of-hospital use of DSI are sparse and have not restricted use to hypoxic patients, as originally intended.

Jarvis et al. applied DSI to all patients undergoing prehospital MFAM to prevent hypoxia. They implemented a strict clinical bundle with intentional focus on optimal patient positioning, apneic oxygenation with a nasal cannula at flush rate, administration of ketamine (2 mg/kg) IV, followed by mask ventilation with a positive end expiratory pressure (PEEP) valve and oxygen flowing at flush rate.[14] If these efforts were unsuccessful at achieving an SpO_2 > 94%, no intubation attempts were made, and instead an EGD was placed or bag-valve-mask (BVM) ventilations were continued. Use of DSI in this manner, and strict attention to saturation targets, was associated with markedly lower rates of peri-intubation hypoxia (SpO_2 < 90%).

Waack et al retrospectively described DSI of 40 patients by rigorously trained intensive care flight paramedics in Australia.[26] Ketamine 1.5 mg/kg IV was administered to patients who met indications for RSI but were agitated to the point of limiting preoxygenation efforts. Despite agitation, the median oxygen saturation was 98% before intervention. Following ketamine administration, patients were administered high-flow oxygen via BVM or BVM in combination with a nasal cannula. After three minutes of preoxygenation, a paralytic was administered, and the remainder of the RSI procedure continued. Oxygen saturation increased to 100%, and all patients were successfully intubated, with an 85% first-pass success rate.

Sedating critically ill patients who are on the cusp of decompensation may result in further respiratory compromise or aspiration. Although rare, a brief period of apnea has been associated with rapid IV administration of ketamine.[25-27] Because of the few patients in the existing literature, the true rate of complications with DSI is not yet known. Since the risks of desaturation are significant, we believe DSI has a role in prehospital MFAM for patients that cannot be adequately oxygenated. Routine use of DSI to

prevent desaturation in patients that are currently meeting oxygenation goals may be reasonable but is less well defined.

SCENE TIMES

In out-of-hospital emergency care, there is always a balance to be struck between provision of patient-centered care on scene versus more immediate transport to definitive care with additional treatments en route. This is particularly true with MFAM, where the procedure itself can take quite long, is more challenging while moving or in confined spaces of aircraft, and there is limited evidence showing improved patient outcomes. Hopefully, we have moved away from dogma-based phrases such as “stay and play” or “scoop and run” to a measured approach that considers the evidence, the individual patient condition and location, local preferences, and the abilities of the on-scene care team.

It is important to consider how long it takes to perform an entire MFAM procedure. A recent ground-based study in the United States by Jarvis et al found a median scene time of 42 minutes for patients undergoing MFAM, whereas an air medical study from Australia found medical scene times of over 1 hour. These studies are a reminder that the “rapid” in “rapid sequence intubation” refers to a series of steps performed in “rapid succession” rather than an overall rapid procedure.[14] With practice and training, individual practices can be streamlined to minimize scene delays, but the MFAM procedure should never be rushed to the point where patient safety is jeopardized. Some agencies have also developed strategies such as RSA to both shave time off the procedure and also permit easier MFAM during transport, which in some cases may preclude the need for extended on-scene times.[28]

Ultimately, the on-scene providers must make a very complex decision within the framework provided by agency policy and guidelines. In a patient without a functioning airway, the benefit of a more immediate intervention to allow adequate oxygenation and ventilation clearly exceeds any imperative for rapid transport, unless these things can be safely accomplished simultaneously. On the other hand, in a patient with an illness or injury for which there is a specific time-urgent treatment only available in the hospital setting and their airway is functioning but at risk for

aspiration, the relative risk versus benefit for delays in transport to secure an airway are much less clear.

NUMBER OF PROVIDERS

The ideal or minimum number of providers required to safely perform a complicated MFAM procedure has not been studied in the prehospital or hospital setting. Clearly, the education and experience of the providers is as important as the sheer number of providers, but a lone provider undertaking an MFAM procedure in the back of a moving ambulance is fraught with problems. Adding two or three assistants with minimal training may help off-load specific tasks such as mask ventilation but still requires the team leader to supervise everyone's actions and does not provide a system of checks and balances. This scenario should be left only to the most experienced of prehospital providers. Some systems require three paramedics for any MFAM procedure, but that is a luxury that few EMS systems can afford.[14] We believe there should be at least two skilled clinicians present who are both "fully competent" in delivering safe MFAM to allow for collaboration, appropriate challenge, and interchangeability. Additional providers can further enhance efficiency and safety if they have appropriate training in their roles. In general, EMS tends to focus on training the primary clinicians, but there should be more emphasis on training appropriate airway assistants in tasks such as running checklists, watching monitors, in-line spinal motion restriction with jaw thrust, assisting with a bougie, and external laryngeal manipulation.

INVASIVE PEDIATRIC AIRWAYS

In the United States, a scant 1.5% of EMS encounters with children require invasive airway management, yet pediatric patients make up only about 10% of all EMS transports.[9,29,30] Likewise, in the United Kingdom, it was recognized that a paramedic is likely to attend a pediatric OHCA only every 12 years. This creates a classic high stakes yet very low-frequency event, which has placed prehospital pediatric intubation in the spotlight. The one prospective, pseudo-randomized, controlled trial on prehospital pediatric airway management dates back to the mid-1990s and found no significant

difference between BMV compared to ETI.[31] It is possible that the subsequent prehospital availability of video laryngoscopy, continuous end-tidal waveform capnography, and RSI might lead to different outcomes 20 years later.[32,33] However, the introduction of EGDs in pediatric sizes has been the greatest impetus for change.

First-pass success of EGD placement in pediatric patients has been shown to exceed first-pass ETI success, which we know is even more challenging the younger the patient is.[9,32,33,34,35] Additionally, first-pass success with EGD placement in pediatric patients appears to be similar to that in adult patients, because the overall use of EGDs by EMS continues to rise.[36,37] Many jurisdictions in the United States and Europe have entirely removed pediatric intubation from the general paramedic scope of practice. We support this focus on BMV and EGD for pediatric cardiac arrest. Pediatric RSI is a completely different situation, where fewer data exist. EMS systems that choose to continue performing pediatric intubation should carefully track their success, complications, and outcomes and must have processes in place to ensure patient safety. Programs that have reported superior intubation outcomes generally also describe utilizing standardized operating procedures and treatment algorithms, the use of cognitive aids such as reference cards and checklists, regularly scheduled simulation training sessions, and a predetermined required number of live intubations a year.[32,33,38,39]

RAPID SEQUENCE AIRWAY

RSA employs the same preparation and sequence of medications as RSI, with the intentional, planned placement of an EGD without any attempt at ETI.[40] RSA is an appealing alternative to RSI when time is limited and/or in circumstances that require rapidly establishing an advanced airway in a confined or ergonomically limited space, such as in an aircraft. A recent retrospective analysis of a large national cohort of prehospital advanced airway management events suggests that EGD placement has a higher first-pass success rate than ETI in all age groups.[41] EGD first-pass success during RSA has been demonstrated to be 76% to 91%, with 84% to 100% overall RSA success rates.[42-44] Of note, many of these RSA success attempts

occurred while ground or air transport was underway and despite predictors of difficulty such as cervical spine precautions.

Some providers may be leery of placing an EGD instead of ETT because of an assumption that an ETT cuff provides substantially better protection against aspiration than an EGD. Interestingly, rates of aspiration and ventilator-associated pneumonia rates following prehospital ETI have not been shown to be statistically different than with prehospital EGD placement, ranging from 8% to 41% and likely reflecting a high incidence of aspiration prior to airway management.[12,45-49] In the specific context of RSA, aspiration rates as low as 9% have been reported in the air medical transport setting and 3% in the hospital setting.[42,50] As EGD designs continue to evolve, with more available sizes, better gastric sealing, and inclusion of channels to facilitate gastric decompression, it is reasonable to believe these aspiration rates may improve.[42,51,52]

As evidence continues to build in its support, RSA is a reasonable MFAM option for local systems and medical directors to consider. RSA might be the only MFAM technique employed or an alternative to RSI/DSI to be used in specific circumstances. Patients selected for RSA should not have significant predictors of EGD failure as per the RODS mnemonic (see Chapter 2). Although the success rate for oxygenation with an EGD is very high, it is never 100% in the real world. RSA should not be used to avoid extensive provider education or to avert the need to have sufficient resources on scene prior to the procedure. There must also be a clear plan in the event of oxygenation failure because mask ventilation is rarely successful when EGD ventilation is unsuccessful. This may mean using ETI as the “rescue technique” or moving directly to FONA.

PREHOSPITAL NIPPV

The prehospital use of NIPPV is now routine, particularly for patients with hypoxemia and respiratory distress from suspected pulmonary edema, pneumonia, or chronic obstructive pulmonary disease (COPD) (**Fig. 32.2**). One area of controversy seems to be the appropriate level of licensure to safely employ this technology. The National Association of EMS Physicians recently endorsed the use of continuous positive airway pressure (CPAP) by EMT-Basics, and we agree with this position. The products

specifically designed for prehospital are very simple, and BLS providers have the least other options available to intervene in these conditions. It is also noteworthy that millions of individuals throughout the world sleep with CPAP in their homes every night.

Figure 32.2: Prehospital use of noninvasive positive pressure ventilation has become a common technique to manage respiratory distress and hypoxemia.

Another area of controversy without any significant literature to provide guidance is the use of CPAP in patients with altered mental status. Despite long-standing guidelines to the contrary, it is our opinion and experience that CPAP can be applied safely in selected patients with altered mental status in the prehospital setting when other options are limited, as long as the providers are constantly attending and monitoring the patient while positioned close enough to immediately remove the mask in the event of vomiting.

INITIAL TRAINING AND SKILL MAINTENANCE

Studies of human behaviors and how we learn show that skills requiring muscle memory and decision making in pressured environments benefit from a certain amount of repetition-based training.[53-55] This applies to both ETI and extraglottic devices, where familiarity and experience reduce provider stress, decrease complications, and increase procedural success. There is little consensus, however, on the specific number of procedures that should be completed in the educational phase to achieve a nominal "competence." Likewise, not all localities are able to require live airway procedures. Research demonstrates little improvement in success or complication rates in paramedic students during their first 13 intubation attempts but significant improvement between the 14th and the 30th attempt. By the 30th intubation, most students were achieving 90% first-pass success in that controlled environment.[56]

Turning research into standards, the U.S. Committee on Accreditation of Education Programmes for Emergency Services Professionals (CoAEMSP) recommends a combination of a minimum of 50 "Airway Encounters" across all age ranges with 100% success in 20 consecutive encounters.[57] The United Kingdom-based College of Paramedics consensus framework for safe and effective intubation for paramedics determined that in excess of 25 intubations were required in a variety of clinical settings in order to achieve a 90% first-pass success rate.[58] Both of these standards are for the specific skill of laryngoscopy and tube passage, not for the much more complicated scenario of MFAM. Just because a clinician has the technical skills to intubate, it does not mean they have the cognitive skills or experience to perform MFAM.

The ongoing maintenance of these airway skills is also an area with little related evidence. Wang found that patients had a better outcome when attended by a paramedic with more airway experience in the previous five years. The UK College of Paramedics consensus standard is that a minimum of two intubations per month should be logged for each patient age group for which intubation is permitted (infant, child, and adult); these can be in clinical practice or in a simulation setting.[58] Similarly, the U.S. Commission on Accreditation of Medical Transport Systems (CAMTS) requires no fewer than one successful airway procedure per quarter for each type of airway utilized for each age group in scope of care.[59] In practice, these intubations are often performed quickly on a manikin that the

providers have intubated hundreds of times to “check a box.” It is hard to believe that this adds substantially to a provider’s readiness to perform a critical procedure under challenging conditions.

Skill dilution among multiple providers is also a real issue. In some situations, it may be reasonable to restrict specific airway skills to a smaller cadre of providers to ensure that they are able to maintain competence. For example, one system might train all paramedics in extraglottic placement for OHCA, but MFAM might be restricted to a limited group of critical care paramedics.

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Section VIII

Special Clinical Circumstances

33 The Unstable Patient: Cardiopulmonary Optimization for Emergency Airway Management
34 The Trauma Airway
35 The Neurocritical Patient
36 Reactive Airways Disease
37 Distorted Airways and Acute Upper Airway Obstruction
38 The Pregnant Patient
39 Cardiovascular Emergencies
40 Intubating the Highly Infectious Patient
41 The Massively Soiled Airway
42 The Geriatric Patient
43 The Morbidly Obese Patient
44 Foreign Body in the Adult Airway
45 Safe Extubation in the Emergency Airway Patient

CHAPTER 33

The Unstable Patient: Cardiopulmonary Optimization for Emergency Airway Management

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THE CLINICAL CHALLENGE

The primary goal of airway management is to maintain airway patency and support systemic oxygenation and effective ventilation in patients who cannot sustain these vital functions on their own. Unlike elective intubation in the operating room, intubation in critical illness is performed because cardiorespiratory physiology is disturbed. As such, these patients are particularly vulnerable to the adverse consequences of apnea and hemodynamic changes associated with induction and positive-pressure ventilation. Furthermore, failure to maintain oxygenation and ventilation during airway management leaves patients at risk for hemodynamic deterioration and cardiac arrest.

In the context of the unstable patient, the emergency airway manager is faced with patients who are hemodynamically compromised or cannot maintain adequate gas exchange prior to intubation. These patients are particularly vulnerable to rapid decompensation during and after the procedure. This chapter will focus on techniques to decrease the risk of deterioration during intubation of the unstable patient. A clear understanding of pertinent principles and physiology helps to optimize the peri-intubation period (see Chapter 4).

OPTIMIZATION FOR FIRST LARYNGOSCOPY ATTEMPT SUCCESS

Airway management of the critically ill patient is a high-risk situation. Determining the need for, and timing of, intubation requires balancing respiratory and cardiovascular considerations in these fragile patients. The airway manager should optimize conditions to achieve first-pass success, because prolonged or repeated attempts with laryngoscopy are associated with increased risk of adverse events (see Chapter 23). **Box 33.1** summarizes important practical issues and modifications required for safe airway management of unstable critically ill patients.

BOX 33.1 Considerations and Modifications Necessary for Unstable Patients

- **Hemodynamic monitoring and optimizing preintubation status**
  - Review current hemodynamic status for high-risk features
    - Hypotension, SI ≥0.8, pulmonary hypertension, RV failure, pericardial effusion
  - Establish monitoring for precipitous hemodynamic decline
    - Consider invasive, continuous arterial monitoring for high-risk patients
  - Confirm adequate IV access for rapid fluid boluses and/or vasopressor infusion
  - Empiric fluid loading prior to airway management (ie, 20 mL/kg crystalloid) in absence of fluid overload or RV failure
  - When appropriate, delay intubation to improve hemodynamic status
  - Initiation or immediate availability of vasopressor support to treat or avoid hypotension
- **Preoxygenation**
  - Suboptimal preoxygenation resulting from high systemic oxygen extraction, ineffective spontaneous breathing, shunt physiology, or equipment limitations
  - Rapid desaturation limiting period of apneic normoxia for laryngoscopy

- Preoxygenation with positive pressure or HFNO should be considered. If unavailable, standard NRB plus standard nasal cannula up to the flush flow rate should be used.
- **RSI and drug use**
  - Greater untoward cardiovascular effects of RSI drugs
  - Need for reduced dose sedative-hypnotic agent
  - Slower onset of action of RSI drugs
  - Awake intubation is an option in some patients
- **Postintubation management**
  - Expected ventilatory requirement should guide intubation plan. Patients with very high minute ventilation may require awake intubation to control their own respiratory drive
  - Lung-protective ventilation (≤7 mL/kg IBW) for all patients
  - Avoid dynamic hyperinflation and auto-PEEP
  - Low-dose titrated analgesia and sedation

Timing of Airway Management

Unstable patients add complexity to the airway management plan. The very procedure intended to secure the airway and improve gas exchange may contribute to patient deterioration when the traditional "A-B-Cs" of resuscitation are rigidly pursued. Prioritization of immediate airway management versus preintubation support is a common clinical dilemma. Three main considerations may assist with the decision:

- **What is the reversibility and severity of respiratory compromise?**

  The exact pathophysiologic mechanism may not be fully understood in the initial moments of critical illness in the emergency department, but when available, knowledge of the underlying pathophysiology responsible for inciting respiratory compromise is important for determining the best course of action. As an example, acute cardiogenic pulmonary edema with reversible precipitants (ie, uncontrolled hypertension or volume overload) often responds to aggressive medical therapy in minutes, averting the need for intubation. In contrast, hypoxemia caused by pneumonia or acute respiratory distress syndrome (ARDS) does not reverse rapidly, and consideration of early intubation is prudent to avoid worsening gas exchange. Severe intrapulmonary shunt physiology that accompanies these conditions also contributes to difficult preoxygenation. These patients are at high risk for rapid desaturation during intubation, which can lead to cardiovascular collapse prior to successful endotracheal tube placement.

  Noninvasive positive-pressure ventilation (NIPPV) and high-flow nasal oxygen (HFNO) are effective methods of managing acute respiratory failure in many patients. However, it is vital to identify patients who are failing these modalities and require tracheal intubation. Sustained high F_{IO_2} requirement (>75%) to maintain oxygen saturation (Sp_{O_2}) >92% indicates severe intrapulmonary shunt, and intubation should be strongly considered in the absence of immediate reversibility. Additionally, a high ROX index [(Sp_{O_2}:F_{IO_2})/RR] <3.85 indicates a high likelihood of failure in patients on HFNO. Delaying intubation until manifestation of refractory hypoxemia is associated with a high incidence of peri-intubation complications and adverse outcomes.

  Acute respiratory failure caused by obstructive lung diseases, such as asthma or chronic obstructive pulmonary disease (COPD), often responds to noninvasive ventilation. Mechanical ventilation of the patient with severe obstructive lung physiology is complicated, and intubation is often used as a last resort after unequivocal failure of NIPPV and medical support. However, these patients require vigilant monitoring to recognize the early signs of deterioration that help avoid delayed intubation in the setting of severe hypercapnic acidosis.

  Patients with ventilatory failure caused by a metabolic acidosis present different management considerations. In patients with a metabolic demand that outstrips their ability to compensate because of shock (eg, sepsis), the metabolic acidosis is often best improved by early intubation to reduce the respiratory work of breathing and oxygen consumption by the respiratory muscles. However, when the metabolic demand outstrips compensatory capability because of organic acid formation, such as diabetic ketoacidosis or salicylate toxicity, maintaining and supporting spontaneous respiration to avoid intubation, given the patient's ability to protect their airway, is the best course of action. This is attributable to the physical limitations of the

mechanical ventilator in meeting the ventilatory requirements required to compensate for the metabolic acidosis that will not improve with offloading of respiratory muscle work.

- **What is the current cardiovascular status and risk of peri-intubation deterioration?**

Cardiovascular shock is the final common pathway for many life-threatening diseases. Preintubation hemodynamic instability increases the likelihood of severe complications, including cardiac arrest, during or following intubation. Postintubation hypotension (PIH) complicates up to 50% of intubations in critically ill patients and is strongly associated with adverse outcomes, including death. Rapid sequence intubation (RSI) and mechanical ventilation can have a substantial negative impact on the already fragile cardiopulmonary status. Structured assessment of cardiovascular status coupled with preinduction hemodynamic preparation are important facets of emergency airway management.

Work of breathing can be substantial and is often underestimated. Patients in shock may expend up to 20% or more of their cardiac output on ventilation, and intubation of patients who are failing cardiovascular resuscitation is frequently advocated to allow redistribution of blood flow to other vital organs. The cause of shock is an important consideration in the decision and timing of intubation in shocked patients. Effects of positive-pressure ventilation on cardiac function vary depending on the underlying cardiovascular state. Positive intrathoracic pressure reduces transmural cardiac pressure and thereby reduces left ventricular afterload. This impact may improve the performance of severe left ventricular dysfunction. In contrast, patients with normal or mildly reduced function suffer greater impact because of impedance of venous return. Prioritizing early fluid resuscitation and use of vasopressor support to maintain systemic pressure and venous return during induction sympatholysis is important for these patients, especially those with prominent vasodilation (ie, sepsis, cirrhosis, and anaphylaxis).

In contrast to vasodilatory shock states and left heart disease, induction and mechanical ventilation can precipitate cardiovascular collapse in other forms of shock. Decompensated right heart failure is very sensitive to the increase in pulmonary vascular resistance that is normally induced by mechanical ventilation. Patients with cardiac tamponade preserve venous return via intense peripheral vasoconstriction. Loss of sympathetic tone with induction and initiation of mechanical ventilation are associated with cardiovascular collapse and arrest in patients with both of these conditions, and delaying intubation for effective therapies (including emergency pericardial drainage) is prioritized over early intubation. Bedside echocardiography can be a useful tool in evaluating the hemodynamic profile of a critically ill patient and in predicting the hemodynamic response to intubation.

Most of the critically ill patients present in *compensated* shock with a narrow pulse pressure but sustained normotension. Episodic or sustained hypotension characterizing *uncompensated* shock is a late sign of hypoperfusion that develops when physiologic mechanisms to maintain normal perfusion pressure are overwhelmed. Mean arterial pressure (MAP) <65 mm Hg, systolic blood pressure (SBP) <90 mm Hg, or MAP >20 mm Hg below baseline are important signs even in the absence of overt clinical hypoperfusion. Peri-intubation cardiac arrest rates complicated up to 15% of patients undergoing emergency intubation in the context of hypotensive shock. Efforts should focus to establishing improved hemodynamic stability prior to induction of patients in shock unless immediate intubation is absolutely required.

Unfortunately, SBP is an imperfect single indicator of cardiovascular status, and normal or elevated blood pressure should not be interpreted as an unequivocal sign of adequate perfusion. Shock index (SI), calculated as HR/SBP, is a simple marker of cardiac efficiency that helps identify vulnerable patients despite deceptively normal blood pressure. Elevated SI is associated with cardiovascular deterioration across a range of clinical conditions, including emergency intubation. Preintubation SI ≥0.8 independently forewarns of peri-intubation hemodynamic deterioration. However, one-third of patients develop peri-intubation deterioration below this threshold, and all patients undergoing emergency intubation should be considered at risk.

Inadequately oxygenated patients are at extremely high risk for desaturation during intubation, which increases the risk of hemodynamic decompensation. Medications and positive-pressure ventilation may also reduce cardiovascular performance and precipitate irreversible decompensation. Both must be titrated carefully to the patient’s cardiovascular status.

Inadequate spontaneous breathing is a late sequela of shock. Respiratory failure in patients with shock, particularly sudden hypoventilation (ie, bradypnea or apnea), often signifies impending cardiac arrest and requires immediate attention. Prompt respiratory support is indicated but must be coordinated with immediate

cardiovascular support. Less severely ill patients may benefit from supplemental oxygen or bag-valve-mask support to optimize preoxygenation, whereas improvement of cardiovascular status is gained through administration of crystalloid and vasopressor support.

- **What is the anticipated clinical course?**

  Many critically ill patients demonstrate a biphasic course wherein early resuscitation slows the spiral of shock and organ dysfunction, only to be followed by deterioration hours later. In most instances, hypotension and malperfusion are improved but not entirely reversed by initial therapy. Tissue edema stemming from volume resuscitation, the progression of end-organ dysfunction (including acute lung injury), cumulative work of breathing, and metabolic debt combine to exhaust physiologic reserve, leading to respiratory failure minutes or hours following initial "successful" resuscitation. Frequent reassessment of critically ill patients is required, with particular attention to respiratory status. Increasing the respiratory work or oxygen requirement signals worsening of acute lung injury. Hemodynamic status may also subtly, but progressively, deteriorate, indicated by malperfusion or escalating vasopressor support. Intubation should occur early when this downward cycle is identified, rather than wait for overt cardiovascular or respiratory failure.

Preoxygenation Considerations in the Unstable Patient

Optimizing preoxygenation is more difficult in critically ill patients. Ineffective spontaneous breathing, decreased pulmonary and systemic perfusion, high systemic oxygen extraction, high shunt fraction, and equipment limitations all compromise preoxygenation. Although saturated hemoglobin accounts for most of the blood oxygen content, systemic oxygenation is regulated (and limited) by cardiac performance. Even with optimal preoxygenation, the rate of desaturation is dependent on cardiovascular status and systemic oxygen extraction. The clinical repercussion is a marked reduction in the period of apneic normoxia to complete intubation. Hypercapnia during intubation also has the potential to exacerbate acidemia, further increasing this risk.

Standard methods of preoxygenation are often inadequate in critically ill patients. Preoxygenation with a non-rebreather (NRB) mask for 3 minutes or eight vital capacity breaths is extrapolated from data in the operating room, where NRB masks create a tight seal and patients are on a closed circuit. Outside of the operating room, NRB masks are rigid, poor fitting without a seal, and rely on filling an attached reservoir with oxygen to increase F_{IO_2} close to 100%. Without the mask seal, room air is entrained around the mask and dilutes the oxygen content provided from the reservoir. High minute ventilation can also easily outstrip oxygen flow, resulting in NRB preoxygenation approximating 50% to 65% F_{IO_2}. When oxygen flow is increased to the "flush flow" rate of 40 to 70 L/min, an F_{IO_2} closer to 100% can be maintained with a standard NRB mask. In addition, patients with shunt physiology exhibit hypoxemia refractory to increased F_{IO_2}. For these reasons, advanced preoxygenation modalities with either NIPPV or HFNO is advocated to provide higher F_{IO_2} and promote alveolar recruitment with positive end-expiratory pressure (PEEP). Newer high-flow nasal cannula (HFNC) devices that provide heated and humidified oxygen at flow rates of 30 to 70 L/min are useful for preoxygenation in patients who cannot tolerate NIPPV. Data comparing HFNC devices to standard methods of preoxygenation in critically ill patients have been mixed, but in all but the most severely hypoxemic patients where RSI is planned, they appear equivalent. Lastly, low-dose inhaled vasodilators such as inhaled nitric oxide or inhaled prostaglandins may decrease ventilation-perfusion mismatch and improve preoxygenation. This is typically reserved for patients being intubated in the ICU and is rarely available in time for an emergency department intubation.

Oxygen provided to the upper airway during the apneic period may prolong the safe duration of apnea during laryngoscopy. Continuous oxygen extraction by the pulmonary circulation during apnea creates a gradient by which oxygen delivered to the upper airway diffuses into alveoli. Data on apneic oxygenation in critically ill patients are also mixed; however, this low-cost intervention is minimally disruptive during emergency airway management and is advocated in high-risk populations.

Systemic oxygenation during intubation is critical. Hypodynamic cardiovascular performance results in significant lag in peripheral Sp_{O_2} compared to central arterial oxygenation. The delay is exacerbated by signal averaging of pulse oximetry (see Chapter 11) and accentuated during hypoxia (ie, starting at the inflection point of the oxyhemoglobin dissociation curve). During acute arterial desaturation, the repercussion of this delay is that central arterial oxygenation can lag the peripheral Sp_{O_2} monitor output for up to 60 to 90 seconds. Conversely, Sp_{O_2} response may be disconcertingly delayed following successful intubation and 100% oxygen delivery following intubation. Forehead and ear probes are closer to the heart and respond more quickly than distal

extremity probes. Forehead reflectance probes are often preferred in critically ill patients for this reason, and they provide more reliable signal detection during hypotension. Limited detection of cutaneous arterial pulsatility generally reduces accuracy of pulse oximetry with SBP <80 mm Hg.

Hemodynamic Optimization

Most critically ill patients have a disturbance in volume balance, exaggerating the response to induction agents and positive intrathoracic pressure. These volume balance disturbances are precipitated by volume depletion (eg, hemorrhagic shock), volume overload (eg, nephrogenic pulmonary edema), vascular compliance abnormalities (eg, decreased systemic vascular resistance in sepsis), or cardiac dysfunction (cardiogenic pulmonary edema, right ventricular [RV] failure). A thoughtful approach to resuscitation is necessary to guide targeted therapies specifically at the underlying pathophysiology.

Establish adequate intravenous access to allow for aggressive resuscitation. Second, determine volume responsiveness. There are several dynamic assessments of volume responsiveness available to determine whether a patient's cardiac output is likely to respond to a fluid challenge. Although most patients will respond to an empiric fluid challenge, assessment of volume responsiveness should be performed in unstable patients to avoid the untoward effects of volume overload. In patients who have been fluid resuscitated or who are not responsive on dynamic assessment, initiate vasopressor support. For patients who are unstable prior to intubation, continuous infusions are preferred over bolus infusions. In patients who are at high risk for PIH, prepare vasopressors for rapid initiation.

Given the risk associated with intubation of patients in hemodynamic crisis, close hemodynamic monitoring is indicated. Continuous cardiac monitoring with frequent noninvasive blood pressure recording at least every 3 to 5 minutes should be performed in the peri-intubation period. Initiate continuous monitoring during the preintubation period. Regardless of the measurement tool, it should be remembered that blood pressure is not equivalent to blood flow (ie, cardiac output and oxygen delivery). Progressive bradycardia not associated with hypoxia or laryngoscopy is a frequent sign of severe shock and impending cardiac arrest.

Induction

Drugs commonly used for intubation can be a double-edged sword in the critically ill. They facilitate intubation but can have severe adverse cardiovascular consequences, including precipitation of shock and cardiac arrest. Patients with reduced physiologic reserve because of hypovolemia, vasodilation, or abnormal cardiac function are at higher risk for adverse events during airway management. Patients with hypotensive shock represent the extreme example. Most shock states are associated with high sympathetic tone, which serves as a compensatory mechanism to maintain critical cardiac output.

Most induction agents induce potent sympatholysis and attenuate reflex sympathetic discharge during laryngeal manipulation. Any drug that extinguishes endogenous catecholamine response, including opiates, sedative-hypnotic agents, and neuroleptics, can have a similar deleterious impact. Reduction of endogenous sympathetic tone leads to venous and arterial vasodilation with decreased venous return and hypotension. Some anesthetic agents also induce direct myocardial depression.

Drug choice must be considered carefully. Even at reduced doses, induction obliterates endogenous catecholamines with subsequent arterial and venous vasodilation. The reduced pressure gradient for venous return induced by systemic venodilation is compounded by positive intrathoracic pressure on initiation of mechanical breathing. In some critically ill patients, awake intubation with preservation of spontaneous respiration is the best course of action because of predicted difficulty either with intubation or with mechanical ventilation after intubation. Sedative induction drugs exhibit similar sympatholysis but are essential to facilitate RSI. Adverse cardiovascular effects are both agent- and dose dependent. Commonly recommended doses are based on patients with normal hemodynamics and cardiovascular reserve and can therefore be hazardous to critically ill patients. Frank hypotension or compensated shock requires a dose reduction of one-half to one-third of the standard dose. Reasonable sedation and amnesia is ensured with the recommended agents, particularly with proper management of sedation and analgesia in the immediate postintubation period.

Cardiovascular effects vary with sedative-hypnotic agent. Etomidate and ketamine are widely regarded as the most hemodynamically stable induction agents; however, despite their improved cardiovascular effects, both etomidate and ketamine require dose adjustment for administration to shocked patients (eg, etomidate 0.1-0.15 mg/kg or ketamine 0.5-0.75 mg/kg). Recent registry data suggest that ketamine may precipitate hypotension more

often than etomidate during emergency department intubation, particularly in patients with longer periods of illness and less adrenal reserve. In this setting, indirect catecholamine release from ketamine is minimal and overtaken by its myocardial depressant effect. Regardless of the agent, it is better to err on the side of too little rather than too much. Airway managers should anticipate delay in drug onset resulting from dose adjustment and the prolonged circulation time.

Neuromuscular blocking agents (NMBAs) pose little hemodynamic risk and should be dosed normally. Succinylcholine and rocuronium are both hemodynamically stable NMBAs. In patients with identified difficult airway attributes, awake intubation using a flexible endoscope, facilitated by topical anesthesia and limited (or no) sedation, addresses the difficult airway and also avoids the potential hypotension of induction agents. Intubation with succinylcholine alone is not recommended but might be required for the obtunded patient with severe shock or impending cardiac arrest who necessitated muscular relaxation for intubation and is unable to tolerate a small dose of induction agent.

Postintubation Management

Mechanical Ventilation

Following intubation, positive-pressure ventilation should be initiated with caution. Positive intrathoracic pressure limits venous return to the right heart, which is accentuated during hypovolemia. Pathologic states of tension pneumothorax and auto-PEEP exacerbate intrathoracic pressure and negative hemodynamic effects. Although most clinicians recognize the risk associated with tension pneumothorax, dynamic hyperinflation is much more common. Intentional or inadvertent hyperventilation leads to dynamic hyperinflation if expiratory time limits complete tidal volume (TV) elimination. Dynamic hyperinflation results in retained intrathoracic volume, which ultimately results in positive intrathoracic pressure known as auto-PEEP and impedes venous return. The risk of dynamic hyperinflation is increased with obstructive lung disease, but any patient can develop auto-PEEP under positive-pressure breathing. Unrecognized auto-PEEP can lead to irreversible hypotension and cardiac arrest.

Immediately after intubation, hyperventilation with an inappropriately high rate and TV is particularly common during manual bag ventilation. This is a vulnerable period given the simultaneous action of induction anesthesia. Recognize that most resuscitation bags have 1500 mL reservoirs and require single-hand ventilation to provide TV approximating 500 mL. Similarly, rapid re-expansion of the bag following breath delivery is not a cue for the next breath, and a clock second hand or counting cadence should be used to ensure that the rate is not excessive. The airway manager needs to be particularly attentive to the risk of manual hyperventilation when other staff provide this support. Specific instruction is required regarding both volume (extent of bag squeeze) and rate (counting cadence, such as “1, 2, 3, 4, 5, breath, 1, 2, 3, 4, 5, breath…”). That sufficient time is allowed for complete expiration can be ascertained by simply listening to the patient’s chest during ventilation. The chest should be quiet, representing completion of expiratory airflow, before initiation of the subsequent breath. Interrogation of the ventilator time-flow graphics to confirm return to zero flow at the completion of each breath cycle is a more sophisticated analysis of the same issue.

Mechanical ventilation strategy depends mainly on the underlying pathophysiology. Lung-protective ventilation should be provided with TV ≤7 mL/kg of ideal body weight (IBW) for all patients. See Chapter 10.

Postintubation Sedation

Postintubation sedation holds the same potential to induce sympatholysis-related hypotension as induction agents. The first priority is patient comfort and patient-ventilator synchrony. Sedation requirements are frequently overestimated. It is crucial to titrate analgesia and hypnotics to patient condition. Although many prefer benzodiazepines (eg, lorazepam and midazolam) to propofol because of perceived hypotension risk, appropriately titrated dose of the selected agent is likely most important. Intermittent or continuous opioid infusions are a growing first choice for postintubation sedation. In the absence of painful invasive procedures, light sedation that maintains patient tolerance of tracheal intubation is preferred over deeper sedation, which may worsen hypotension or increase vasopressor requirements. Despite its favorable hemodynamic properties, etomidate should not be used for postintubation sedation because of the risk of adrenal suppression.

PIH is a common clinical situation but should not be interpreted as an innocuous consequence of intubation. PIH occurs in one-quarter of normotensive patients undergoing emergency intubation and is severe (SBP <70 mm Hg) in up to 10% of cases. PIH is independently associated with increased risk of in-hospital death. Whether PIH directly contributes to worse outcome or merely represents a high-risk marker of severe disease is unclear. In either

case, the risk associated with PIH warrants an early and organized hemodynamic resuscitation response similar to systemic hypotension (uncompensated shock) unrelated to airway management.

SUMMARY

The ultimate goal with airway management is to maintain adequate systemic oxygenation, ventilation, and perfusion. Unstable patients have altered physiology that makes this goal complicated. Although intubation is an essential part of the resuscitation of a critically ill patient, preintubation management, the intubation technique, medications, and postintubation mechanical ventilation strategy impact peri-intubation hemodynamics that are associated with patient outcomes (**Table 33.1**). Careful planning, coordinated resuscitation, and peri-intubation management seek to optimize safe intubation and outcomes.

TABLE 33.1 Strategies to Optimize Intubation in Unstable Patient Situations

	Preoxygenation	Hemodynamic Optimization	Induction	Postintubation Management	Comm
Hypovolemic shock	• Facemask + nasal cannula • HFNO • Positive pressure likely to worsen hypotension until fluid resuscitation performed	• Rapid fluid boluses • Early transfusions when necessary • Large-bore IV access	• Hemodynamically neutral sedative • RSI	• Lung-protective ventilation • Avoid auto-PEEP	• Fl pr va gi sy va re (S
Septic shock	• Facemask + nasal cannula • HFNO • NIPPV if severe hypoxemia (pneumonia/ARDS) vs awake intubation	• Empiric fluid resuscitation • Dynamic assessment of volume responsiveness • Fluids if responsive • Norepinephrine infusion	• Hemodynamically neutral sedative at decreased doses • RSI	• Lung-protective ventilation • Avoid auto-PEEP	• H pr va or se ur et
Right ventricular failure	• Facemask + nasal cannula • HFNO • NIPPV with low PEEP	• Bedside ultrasound assessment of RV function • Gentle fluids • Early vasopressor infusions • Pulmonary vasodilators	• Hemodynamically neutral sedatives	• Low mean airway pressure • Prevent atelectasis, hypoxemia, and hypercapnia	
Cardiac tamponade	• Facemask + nasal cannula • HFNO • NIPPV likely to worsen hypotension	• Fluid resuscitation • Delay intubation for priority of pericardiocentesis when possible	• Hemodynamically neutral sedative at decreased doses • RSI	• Aggressive fluid resuscitation • pericardiocentesis	
Severe metabolic acidemia (MA)	• Facemask + nasal cannula • HFNO • NIPPV	• Appropriate balanced or alkalinizing intravenous fluid	• Consider avoiding neuromuscular blocking agents if	• Recognize need to provide respiratory	

		(IVF) resuscitation to avoid worsening MA • Insulin drip if DKA • Consider early hemodialysis for toxic associated MA	high minute ventilation (>30 L/min) due to limits with mechanical ventilation	compensation for MA • Match preintubation minute ventilation • Patient-ventilator synchrony	
Hypoxemic respiratory failure	• NIPPV preferred if severe • HFNO • Facemask + nasal cannula • Consider awake if refractory	• Dynamic assessment of volume responsiveness • Limit unnecessary IVF • Norepinephrine infusion	• Hemodynamically neutral sedative • RSI	• Lung-protective ventilation • Continuous paralytics • High PEEP if refractory hypoxemia	• M w se ha dy T as ve re sh pe

EVIDENCE

Who is likely to develop peri-intubation hypotension or circulatory collapse?

In a retrospective cohort study of all patients intubated in an urban emergency department over a 1-year period, a preintubation SI of ≥0.8 had a sensitivity of 67% and a specificity of 80% for PIH.[1] Similarly, a preintubation SI >0.90 has an odds ratio of 3.17 (95% CI, 1.36-7.73) of developing PIH for patients intubated in the intensive care unit.[2] Although preintubation SI is useful, one-third of patients with a normal SI developed PIH. In a recent multicenter, multinational observational study, nearly half of critically ill patients had a complication, most commonly hypotension (43%), whereas observational studies and two recent prediction scores have found older age, hypotension or shock prior to intubation, intubation for respiratory failure, and higher APACHE score are all strong predictors of postintubation cardiovascular collapse.[3-7] A recent analysis of nearly 15 000 intubations from the National Emergency Airway Registry revealed that patients who presented with either preintubation shock or hypoxemia had an increased risk of peri-intubation cardiac arrest with an adjusted odds of 6.2 and 3.1, respectively.[8]

What is the evidence for hemodynamic complications with intubation?

PIH is reported in nearly half of patients intubated in the ICU.[9] Severe cardiovascular collapse was recently reported in 30% of patients in an analysis of 1400 consecutive intubations in 42 ICUs.[10] Peri-intubation hypotension increases not only the immediate risk of death with intubation but also the risk of in-hospital mortality, longer ICU stays, and prolonged mechanical ventilation.[11,12]

Is there any evidence to recommend the best method of preoxygenation?

In a prospective study of 42 consecutive intubations, Mort showed that best efforts to achieve optimal facemask preoxygenation in critically ill patients were effective in less than 20% of patients.[13] He repeated the study and doubled the preoxygenation time from 4 to 8 minutes, with no significant difference in efficacy.[14] A randomized controlled trial showed that NIPPV significantly improved preoxygenation compared to facemask preoxygenation in critically ill ICU patients.[15] Evidence on HFNC use is mixed. Two randomized controlled trials show no significant difference in desaturation rates, whereas one observational study shows benefit in the ICU.[16-19]

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CHAPTER 34

The Trauma Airway

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THE CLINICAL CHALLENGE

Effective airway management is a cornerstone of resuscitation of the critically injured patient. Although the nature and timing of airway intervention is influenced by assessment and prioritized management of multiple injuries, the fundamental principles of trauma airway management are no different than those applied to management of the airway in other complex medical situations. A consistent approach and a reproducible thought process will maximize success.

The requirement for intubation in a trauma patient depends on myriad factors that reach well beyond the airway. The indications for intubation, discussed in Chapter 1, include failure of the patient's ability to maintain or protect the airway (as in traumatic coma). In such cases, the need for intubation is clear. Failure of ventilation or oxygenation is less common. The former is often related to intoxicants or direct chest injury, such as pneumothorax or hemothorax. The latter may arise not only from direct chest trauma but also from pulmonary edema caused by diffuse capillary injury in the lung from shock ("shock lung") or from acute respiratory distress syndrome. One of the most common indications for intubation in trauma, however, is also the most challenging. This is the "anticipated clinical course," wherein multiple injuries, need for imaging, hemodynamic instability, need for painful procedures or surgery, likelihood of deterioration, combative behavior, and other considerations lead to a decision to intubate—even though the airway itself, oxygenation, and ventilation are all adequate.

In a recent analysis from the National Emergency Airway Registry (NEAR) database, trauma intubations accounted for 23% of all emergency department (ED) intubations, with head injury, multisystem trauma, face/neck trauma, and combativeness being the most common traumatic indications (see Evidence section).

APPROACH TO THE AIRWAY

Although many trauma intubations turn out to be straightforward, all should be considered potentially difficult. A targeted patient assessment should be performed with the aim of answering two fundamental questions. First, will the procedure be confounded by difficult anatomy? Systematic use of the difficult airway mnemonics (LEMON, ROMAN, SMART, and RODS, Chapter 2) will help answer this question. Second, will physiology suffer? This question prompts the clinician to anticipate predictable changes in physiology that may occur before, during, or immediately following intubation, as a result of the injuries present, the procedure itself, or the patient's premorbid condition. Focusing on physiologic optimization (Chapters 3 and 5) will help mitigate adverse hemodynamic consequences of rapid sequence intubation (RSI).

Assessment of Difficulty

Application of the difficult airway mnemonics allows the clinician to rapidly identify patients with a difficult airway at the bedside. It is worth noting that the LEMON mnemonic, originally published in the first edition of this manual, in 2000, is recommended as the airway assessment tool of choice in the current version of advanced trauma life support (ATLS). The mnemonics are provided in detail in Chapter 2 but are adapted here specifically for airway management in the acutely injured patient:

1. *L*: Look externally. Injury to the face, mouth, or neck may distort anatomy or limit access, making the process of intubation difficult or impossible. Robust mask seal may be impaired by facial hair, external bleeding, preexisting physiognomy, or anatomic disruption (RO*M*AN). Injury to the anterior neck, such as by a clothesline mechanism or

hematoma, may confound successful cricothyrotomy (S*M*ART) or extraglottic device (EGD) placement (RO*D*S).

2. *E*: Evaluate 3-3-2. In blunt trauma, the cervical spine is immobilized, and a cervical collar is usually in place at the time that airway decisions must be made. Although a cervical collar is not particularly effective at limiting cervical spine movement during intubation, it does greatly impair mouth opening, limiting both laryngoscopy and insertion of an EGD (*R*ODS). In these cases, hyperangulated video laryngoscopy (VL) often helps facilitate glottic visualization, more so than standard geometry blade shapes. The front portion of the collar should be opened to facilitate the primary survey and removed entirely during intubation or cricothyrotomy while manual in-line cervical stabilization is maintained. Other injuries, such as mandibular fractures, may either facilitate or impair oral access, and mouth opening should be assessed as carefully as possible.
3. *M*: Mallampati. The trauma patient is rarely able to cooperate with a formal Mallampati assessment, but the airway manager should at least attempt to gently open the patient's mouth as widely as possible and inspect the oral cavity for access, using a tongue or laryngoscope blade on the anterior portion of the tongue to gently flatten it and estimate oral access. This maneuver is not "checking the gag reflex." It is, in fact, important to refrain from inadvertently "checking the gag reflex" during mouth opening, because this adds no useful information and may precipitate vomiting. At this time, potential hemorrhage or disruption of the upper airway may also be evident.
4. *O*: Obstruction, Obesity. Obstruction, usually by hemorrhage or hematoma, can interfere with laryngoscopy, bag and mask ventilation (R*O*MAN), or EGD placement (R*O*DS). Obesity in the trauma patient presents the same challenges as for the nontraumatic patient.
5. *N*: Neck mobility. All patients suffering blunt trauma require in-line stabilization of the cervical spine during airway management. By definition, in-line stabilization significantly impairs the ability to place the patient in the sniffing position, and, as a result, direct visualization of the glottis will be predictably difficult. When in-line stabilization is required, other measures to improve glottic visualization such as

optimal external laryngeal manipulation (OELM) or VL should be used. Rescue devices (eg, bougie, EGD, and surgical airway equipment) should be prepared as part of the overall airway management plan. Two areas of controversy are related to the need for spinal immobilization in patients suffering cranial gunshot wounds and those suffering penetrating wounds to the neck. In the former group, there is sound evidence that the amount of force delivered by a gunshot wound to the head or face in and of itself is insufficient to fracture the spine. In both groups, decision-making should be guided by the neurologic examination. Simply stated, a normal neurologic examination is an indication that the neck can be moved slightly to optimize visualization of the airway. A neurologic deficit suggestive of cervical spinal cord injury mandates strict in-line stabilization.

Special Clinical Considerations

The trauma airway is one of the most challenging clinical circumstances in emergency care. It requires knowledge of a panoply of techniques, guided by a reproducible approach (the airway algorithms), sound judgment, and technical expertise. In this section, we describe the considerations unique to several high-risk trauma airway scenarios (see **Table 34.1**).

TABLE 34.1 The "ABCs" of the Trauma Airway

A	• Is there an injury to the Airway?
B	• Is there traumatic Brain injury?
C	• Is there a significant Chest injury? • Is there a risk of Cervical spine injury?
S	• Is the patient in Shock?

A—Injury to the Airway

Here, the very condition that mandates intubation may also render it much more difficult and prone to failure. Direct airway injury may be the result of the following:

- Maxillofacial trauma

- Blunt or penetrating anterior neck trauma
- Smoke inhalation

In cases of distorted anatomy caused by traumatic injury, the approach must minimize the potential for catastrophic deterioration. Airway disruption may be marginal or significant, real or potential. In either case, the guiding principle is to secure the threatened airway early, while more options are preserved and the patient's stability permits a more deliberate approach. Careful decisions guided by the airway algorithms will need to be made about the use (or not) of neuromuscular blockade, the primary method of airway management, and the airway rescue plan. The importance of mobilizing resources (equipment and personnel), strong leadership, and effective communication with the entire team cannot be overemphasized.

As for any other anatomically distorted airway, application of the difficult airway algorithm will often lead to a decision to perform an awake intubation. In patients with signs of significant airway compromise (eg, stridor, respiratory distress, and voice distortion), both the urgency of the intubation and the risk of using neuromuscular blockade are high. When symptoms are more modest, there is more time to plan and execute an airway intervention, but in neither case is delay advisable. The patient's oxygenation should be assessed (ie, "is there time?"), and it should be determined whether RSI is advisable, under a double setup, even though the airway is difficult (see Chapter 5). This will depend on the clinician's confidence about the likelihood of success of oxygenation using a bag and mask or an EGD and intubation by direct or VL. Often, an airway not amenable to direct laryngoscopy (DL) can be managed using a video laryngoscope. In rare circumstances, a precipitous deterioration invokes the "forced to act" RSI principle (Chapter 5). In this circumstance, the need for immediate airway control outweighs the patient's difficult airway attributes and permits a "one best attempt," using neuromuscular blockade, with immediate recourse to a surgical rescue should that one attempt fail. When time permits and the airway is not obscured by blood, often the best approach is awake intubation using a flexible endoscope technique with sedation and topical anesthesia (see Chapter 17). This permits both examination of the airway and careful navigation through the injured area, even when the airway itself has been violated. This is especially true if a

tracheal injury is suspected, because no other method of intubation allows the airway to be visualized both above and below the glottis. When the airway is disrupted, the endotracheal tube used should be as small as is reasonable to maximize the likelihood of success and to minimize the likelihood of additional airway injury.

Smoke inhalation can present on a spectrum from mild exposure to complete airway obstruction and death. The initial assessment should be designed to identify the presence or absence of high-risk historical features (eg, closed space fire) and physical findings (eg, singed nasal hairs, perinasal or perioral soot, carbon deposits on the tongue, hoarse voice, and carbonaceous sputum). When evidence of significant smoke inhalation is present, direct examination of the airway, often with intubation, is important. This is best done with topical anesthesia and token amounts of sedation (only if required) using either a flexible endoscope or video laryngoscope. Both the devices permit evaluation of the airway and immediate progression to intubation, if indicated. Supraglottic edema is an indication for intubation, even if the edema is mild, because progression can be both rapid and occult. Observation in lieu of airway examination can be hazardous because the airway edema can worsen significantly without any external evidence, and by the time the severity of the situation is apparent, intubation is both required immediately and extremely difficult or impossible. If examination of the upper airway reveals that the injury is confined to the mouth and nose, and the supraglottic area is spared (normal), then intubation can safely be deferred, with subsequent examination at the discretion of the operator. If it is unclear whether edema is present, it is useful to periodically perform a repeated upper airway examination (eg, every 30-60 minutes), even if symptoms or signs do not develop or worsen.

B—Traumatic Brain Injury

In the NEAR studies, head trauma was the most common indication for ED trauma airway management. Traumatic brain injury (TBI) is the number one cause of injury-related death worldwide. The principles of management of the neurocritical patient with or without predicted elevated intracranial pressure (ICP) are discussed in more detail in Chapter 35.

When neurologic status is altered, by TBI or spinal injury or both, a rapid but thorough neurologic examination is important before any intubation attempt is undertaken, so that baseline neurologic status is documented to guide subsequent assessments and therapeutic decisions. Airway management decisions in the patient with severe TBI are centered on the prevention of secondary injury; that is, minimizing the magnitude and duration of hypoxia or hypotension. Secondary injury is the term applied when the insult to the injured brain is worsened by hypoxia, hypotension, or both.

Concrete steps can be taken to reduce the risk of secondary injury before, during, and after airway management:

First—Bring the principles of secondary brain injury prevention to the field. Emergency medical service providers should be educated and equipped to begin volume resuscitation and oxygen therapy before the patient arrives in the ED. Maintenance of adequate perfusion pressure (mean arterial blood pressure) and oxyhemoglobin saturation are the keys.

Second—Operators should focus on physiologic optimization and adequate brain perfusion before intubation. Appropriate volume replacement with normal saline solution, blood products, or both may prevent hypotension.

Third—Make wise decisions regarding RSI medications. Etomidate is both neuroprotective and hemodynamically stable and, therefore, makes it an excellent choice for induction during RSI. The dose should be reduced from 0.3 to 0.15 mg/kg in the face of compensated or decompensated hypovolemic shock. Drugs that can precipitate hypotension (eg, propofol, midazolam) should be avoided unless no other options are available. Ketamine is a reasonable alternative in the context of deranged hemodynamics, even with the presence of head injury. Ketamine should also be reduced to 0.5 mg/kg if the patient is in shock.

Fourth—Avoid hyperventilation. Earlier thought to be a basic tool in the management of severe TBI, the use of hyperventilation is now known to lead to poorer outcomes. There is no question that hyperventilation transiently reduces ICP. It does so, however, by reducing central nervous system perfusion, violating the central tenet of secondary injury prevention.

C—Cervical Spine Injury

Severely injured blunt trauma patients are assumed to have sustained cervical spine injury until proven otherwise and require in-line stabilization during airway management. Although in-line stabilization is believed to help protect against spinal cord injury during intubation, it can create several problems as well. Intoxicated or head-injured patients typically become agitated and difficult to control when strapped down on a backboard. Physical and chemical restraint may be required. Aspiration is a significant risk in the supine patient with TBI or if they are vomiting. In the supine position, ventilation may be impaired, particularly for obese patients,

and chest injury may make matters even worse. High-flow oxygen should be provided to all patients, and suction must be immediately available.

The intubation itself should be performed as gently as possible, ideally, using a video laryngoscope and in-line cervical stabilization. Use of OELM will improve visualization of the glottis without compromising spine stabilization. Both the preintubation neurologic status of the patient and the fact that in-line stabilization was used should be clearly documented in the medical record.

VL is superior to standard laryngoscopy when airway management is performed with the neck maintained in neutral position and is the most successful device for trauma intubations (see Evidence section). Better views of the glottis are achieved in less time, and intubation success rates are higher. Traditional flexible endoscopic intubation remains a valuable tool in the patient with cervical spine trauma. Recent fluoroscopic studies comparing cervical motion during standard laryngoscopy, VL, and flexible fiberoptic intubation demonstrate that the flexible endoscopic approach is associated with the least amount of cervical displacement. Translating this information into clinical practice, VL appears to be the best and now widely available approach for most at-risk blunt trauma patients requiring cervical immobilization. Flexible endoscopic intubation should be considered in patients with known or strongly suspected unstable cervical spine fractures or in those with coexisting anterior neck injuries with distorted anatomy, provided sufficient time, appropriate equipment, and expertise are available.

C—Chest Trauma

Both blunt and penetrating chest trauma result in injuries that are extremely relevant to the airway management process. Pneumothorax, hemothorax, flail chest, pulmonary contusion, or open chest wounds all impair ventilation and oxygenation. Preoxygenation may be difficult or impossible, and rapid desaturation following paralysis is the rule. The postintubation delivery of positive-pressure ventilation may convert a simple pneumothorax into a tension pneumothorax. When a pneumothorax is known or suspected, a single provider should perform needle decompression before intubation when feasible. During resuscitations by a trauma team, formal tube thoracostomy can often occur simultaneously

with intubation efforts, provided RSI is planned and the patient is fully induced.

Penetrating chest wounds with the potential to cause cardiac injury deserve special mention. Acute traumatic pericardial tamponade is a rapidly progressive and highly lethal condition. In the setting of tamponade physiology, cardiac output becomes preload dependent. For this reason, cardiovascular collapse can occur following administration of induction agents or use of positive-pressure ventilation. If available, a bedside ultrasound should be performed early in the resuscitation. If pericardial tamponade is detected, it should be relieved before the intubation or immediately following intubation, whenever possible. If urgent intubation is required and a cardiac wound is known or suspected, volume infusion is important to increase cardiac preload. The dose of induction agent (ketamine or etomidate) should be substantially reduced in this setting (eg, 50%), perhaps opting for "amnesia over anesthesia," particularly for the patient in extremis.

S—Shock

Shock in the patient with multiple injuries can be broadly classified as hemorrhagic or nonhemorrhagic (eg, tension pneumothorax, pericardial tamponade, myocardial contusion, or spinal shock). A targeted physical examination and selective bedside testing (chest X-ray, pelvic X-ray, and e-FAST) will help identify the cause(s). As the causes of shock are elucidated and addressed, airway management decisions must consider the erosion of hemodynamic reserve in these patients. Common decisions include the following:

- Should the patient be intubated now, or is there time for physiologic optimization?
- How does the patient's hemodynamic status influence the choice and dose of the induction agent?

Although there is no simple answer to these fundamental questions, the central tenet here is this: The more hemodynamically unstable, the more important it is to resuscitate before intubation to mitigate the potential adverse hemodynamic effects of RSI drugs.

Patients in “compensated shock” can appear deceptively stable. The presence or absence of shock should never be simplistically equated with the presence or absence of a blood pressure reading of <90 mm Hg. Because of adaptive postinjury responses, relatively normal blood pressure is often maintained despite significant hypoperfusion. Hypotension is typically a late finding indicative of significant decompensation. The operator must select the induction agent (and appropriate dose) and determine the rate, timing, and quantity of resuscitative fluid or blood products in the context of the patient’s overall circulatory status and response to resuscitation, rather than be guided only by a systolic blood pressure.

Table 34.2 provides summary guidance on how to anticipate and manage changes in physiology during airway management. See Chapters 20 and 33 for a detailed discussion of both physiologic optimization and airway management in the unstable patient.

TABLE 34.2 Anticipating Changes in Physiology During Trauma Airway Management

Clinical Scenario	Challenge	Considerations
Airway injury		
• Facial/neck trauma	• Will intubation be difficult?	• Rapid sequence intubation (RSI) vs an awake technique? • Identify rescue device(s) • Prepare for surgical airway
• Smoke inhalation	• Will intubation be difficult? • Will there be airway edema? • Will lung injury limit reserve?	• RSI vs an awake technique? • Supraglottic rescue device may not work • Prepare for surgical airway

		• Have a smaller endotracheal tube ready • Anticipate rapid desaturation
Brain and cervical spine injury		
• Brain injury and multisystem trauma with hemodynamic compromise	• Will blood pressure (and central nervous system perfusion) fall further during induction?	• Optimize preload • Reduce dose of etomidate or ketamine • Avoid other induction agents
• Cervical spine	• Is there a risk of spinal cord injury during intubation?	• Blunt trauma patients are presumed to have this risk until proven otherwise • Maintain in-line stabilization • Use of video laryngoscopy or flexible endoscopy if available
	• Will in-line stabilization impair visualization of the airway?	• Use the optimal external laryngeal manipulation during direct laryngoscopy (DL) • Video laryngoscopy is superior to DL
Chest injury		
• Blunt	• Is there a pneumothorax or	• Consider needle chest

	hemothorax? • Will drugs or positive-pressure ventilation precipitate cardiovascular collapse? • Will chest injury limit reserve?	decompression • Optimize preload • Reduced doses of either etomidate or ketamine • Anticipate rapid desaturation
• Penetrating	• Is there a pneumothorax or pericardial tamponade? • Will drugs or positive-pressure ventilation precipitate cardiovascular collapse? • Will chest injury limit reserve?	• Consider needle chest decompression • Optimize preload • Reduced doses of either etomidate or ketamine • Anticipate rapid desaturation
• Shock	• Will drugs or positive-pressure ventilation precipitate cardiovascular collapse?	• Optimize preload • Reduced dose etomidate for induction

TECHNIQUE

Paralysis Versus Rapid Tranquilization of the Combative Trauma Patient

The combative trauma patient presents a series of conflicting problems. The potential causes of combative behavior are numerous and include head

injury, drug or ethanol intoxication, preexisting medical conditions (eg, diabetes), hypoxemia, shock, anxiety, psychiatric disease, and others. The priority is to rapidly control the patient so that potentially life-threatening causes can be identified and corrected and the risk of injury to medical providers is minimized. Controversy exists as to whether such patients ought to undergo rapid tranquilization with a neuroleptic agent or sedative or whether immediate intubation with neuromuscular blockade is appropriate. Rapid tranquilization using haloperidol is well established as a safe and effective means of gaining control of the combative trauma patient who cannot be settled by other means. Both haloperidol and droperidol can be used intravenously in 5- to 10-mg increments every 5 minutes, up to 20 mg IV, or until a sufficient clinical response is achieved. The decision to use rapid tranquilization rather than RSI with neuromuscular blockade depends on the nature of the patient's presentation and injuries. If intubation is required based on the patient's injuries and vital signs, independent of the combative behavior, then immediate intubation is indicated. If, however, the patient is presenting primarily with control problems and does not appear to have injuries that would mandate intubation, then rapid tranquilization is appropriate. In many situations, the decision will not be clear-cut, and judgment and coordination with available staff/resources will be required. Control of the patient is an essential step in overall management.

RSI of the Trauma Patient

Except when consideration of the patient's injuries argues otherwise, RSI is the preferred method of airway management for most injured patients. The potential for difficulty or failure is inherent in trauma airway management, and formulation of a backup (rescue) plan is a key part of preparing for the airway interventions.

As in other critically ill patients, the universal, difficult and failed airway algorithms will guide the clinician in navigating the multitude of unique clinical scenarios that may arise in the injured patient (see Chapter 5). Familiarity with the algorithms and with the drugs and techniques of RSI, and alternative airway techniques, will maximize the likelihood of a positive outcome.

Choice of Neuromuscular Blocking Agent

Succinylcholine (SCh) and rocuronium are both excellent choices for RSI in the trauma patient. SCh is highly desirable because of its rapid, reliable onset and brief duration of action. The latter permits earlier neurologic reassessment in head-injured patients. Suspected elevation of ICP is not a contraindication to SCh. Although spinal cord injury, extensive burns, and severe crush injuries are risk factors for SCh-induced hyperkalemia, the receptor upregulation that can lead to hyperkalemia takes a few days to develop and is not a clinical concern in the acute setting. SCh is contraindicated in these patients beginning 3 days post injury and extending for 6 months (or, in the case of burned patients, until the burns are healed). In all these patients, rocuronium is a suitable replacement. If rocuronium is selected, appropriate attention should be directed to postprocedural sedation in order to mitigate the chance of persistent paralysis with use of a shorter acting induction agent.

Choice of Induction Agent

In most circumstances, etomidate is the drug of choice for patients with trauma, because of its rapid onset, hemodynamic stability, favorable effect on cerebral metabolic oxygen demand, and the extensive experience with its use. However, despite its reputation for hemodynamic stability, etomidate can aggravate hemodynamic status in susceptible patients, leading to the recommendation to reduce the induction dose to 0.15 mg/kg in these patients. The transient depression of steroid synthesis by etomidate has not been shown to adversely affect outcome in patients with hemodynamic shock (see Chapter 21). Induction agent selection is summarized in **Table 34.3**.

TABLE 34.3 Rapid Sequence Intubation Sedative Induction Agent Selection in the Trauma Patient

Clinical Scenario	First Choice	Alternatives
No brain injury		
Hemodynamically stable	Etomidate	Propofol, ketamine
Shock	Etomidate[a]	Ketamine[a]

Brain injury		
Hemodynamically stable	Etomidate	Propofol
Shock	Etomidate[a]	Ketamine[a]

[a]*In the presence of shock, reduce the dose by 25%-50%.*

THE FAILED AIRWAY

The failed airway is managed according to the failed airway algorithm. The LEMON, ROMAN, RODS, and SMART evaluations during the preintubation assessment are intended to minimize the risk of encountering a failed airway. Cricothyrotomy equipment for a "double setup" should always be readily available.

TIPS AND PEARLS

- Airway management of the patient with multiple injuries follows the same general principles as with any other patient. The primary challenge for the intubator is to resist distraction by the patient's external injuries, combative behavior, or the anxiety that accompanies care of the severely injured trauma victim.
- Resist the temptation to simply observe the patient with upper airway injury or smoke inhalation. Delay can lead to disaster. Examine the upper airway periodically with a flexible endoscope passed nasally. Err on the side of intubating when edema is present, even if mild.
- Consider early intubation for potentially unstable patients who are to be moved out of the ED for diagnostic studies or transported to another facility.
- There is substantial and increasing evidence that VL is superior to DL for airway management in the ED. This is especially true in trauma patients (see Evidence section) and those requiring in-line cervical stabilization. Clinicians who manage trauma patients on a regular basis must give serious consideration to routine incorporation of VL. Hyperangulated video laryngoscopes may be better at glottic

visualization than those that are traditionally shaped in patients with cervical collars.

- The hemodynamically compromised trauma patient may be much more severely injured than is apparent. Young patients, in particular, can preserve a reasonably “normal” blood pressure in the face of significant hemorrhage. Occult instability may be suddenly unmasked by the administration of sedative agents or positive-pressure ventilation. If the need for intubation is not immediate, perform physiologic optimization to mitigate the adverse hemodynamic consequences of RSI.

EVIDENCE

Are there large studies of intubated emergency department trauma patients?

The most recent multicenter analysis of trauma intubations comes from the NEAR. In this report of 19,071 intubations, 23% were intubated for trauma.[1] The most common traumatic indications were head injury, multisystem trauma, face/neck trauma, and combativeness, accounting for 75% of trauma airways. Most (94%) were intubated by emergency physicians VL in over 70% of first attempts. RSI was employed in 83% of cases, whereas no meds (ie, cases of traumatic arrest) were needed in another 12%. Difficult airway attributes were common. Seventy-two percent were reported as having reduced neck mobility, and both facial trauma and blood in the airway were noted in nearly 40% of cases.

How often is cricothyrotomy required in trauma patients?

In the same NEAR analysis, only 31 of 4499 patients necessitated a surgical airway (0.7%, 95% CI: 0.5-1.0), and 7 of 31 surgical airways (23%) were done on first attempt.[1] In a recent Japanese airway registry study in which 723 intubated patients with trauma were reviewed, cricothyrotomy was required in 2.2% of patients, with virtually all of those done to rescue a failed airway. When performed, it had a high success rate and a low rate of adverse events.[2]

Is VL superior to DL in trauma patients who are at risk for cervical or head injury?

In a recent propensity scored matched analysis of more than 4000 trauma intubations in NEAR, VL was associated with a propensity matched OR of 2.2 for first attempt intubation success compared with DL. These findings were adjusted for patient and center-level confounders. Centers with both larger trauma volume and higher percentage use of VL had highest first attempt intubation success associated with VL use per center. VL should be the default tool for emergency airway management in the trauma patient.

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CHAPTER 35

The Neurocritical Patient

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THE CLINICAL CHALLENGE

Neurocritical patients requiring intubation are an important subset of emergency department patients needing airway management. The goal is to accomplish placement of a safe and secure definitive airway while maintaining cerebral perfusion pressure (CPP) and limiting or eliminating the risk of secondary brain injury by mitigating hypotension and hypoxemia. For the purposes of this chapter, the discussion will focus on two groups of neurocritical patients, those with status epilepticus and those with elevated intracranial pressure (ICP).

Status Epilepticus

A general discussion of the diagnosis and treatment of seizure disorder is beyond the scope of this book. In the simple, self-limited, generalized seizure, airway management is supportive. Efforts are directed at termination of the seizure and prevention of hypoxia from airway obstruction. Intubation should be considered when the patient's condition declines despite supplemental oxygen or when typical first-line measures fail to terminate the seizure in a reasonable time. For the simple seizure, basic airway maneuvers, expectant observation (most seizures end spontaneously), supplemental high-flow oxygen, and vigilance are usually all that is necessary. Airway protection from aspiration is rarely required in the simple, self-limited seizure because the uncoordinated motor activity precludes coordinated expulsion of gastric contents.

Determining when to proceed from supportive measures to intubation is the main clinical challenge. The Epilepsy Foundation defines *status*

epilepticus as a seizure that lasts longer than 5 minutes or having more than 1 seizure within a 5-minute period, without returning to a normal level of consciousness between episodes. The rationale for 5 minutes (previously 30) was that most non–status-related seizures are much shorter in duration, typically 2 to 3 minutes. The brain's compensatory mechanisms to prevent neuronal damage rely on adequate oxygenation, and cerebral blood flow is often compromised well before 30 minutes, particularly in patients with underlying illness. Evidence also suggests that with longer seizure duration, pharmacologic therapies become less effective. The mortality rate for status epilepticus is greater than 20% and increases with duration of seizure activity. Therefore, intubation should be undertaken early as a part of overall supportive therapy in cases where the seizure is not promptly terminated by anticonvulsant medications. The absolute and relative indications for intubation in the seizing patient are listed in **Box 35.1**.

BOX 35.1 Indications for Endotracheal Intubation for the Seizing Patient

Absolute indications

1. Hypoxemia (Spo_2 < 90%) secondary to hypoventilation or airway obstruction
2. Treatment of underlying etiology (eg, intracranial bleed with elevated ICP)
3. Prolonged seizure refractory to anticonvulsants (to prevent accumulating metabolic debt [acidosis and rhabdomyolysis])
4. Generalized convulsive status epilepticus

Relative indications

1. Prophylaxis for the respiratory depressant effect of large doses of anticonvulsants (eg, benzodiazepines and barbiturates)
2. Termination of seizure activity to facilitate diagnostic workup (eg, CT scanning)
3. Airway protection in prolonged seizures

APPROACH TO THE AIRWAY

Self-Limited Seizure

Most seizures terminate rapidly, either spontaneously or in response to medication, and require only supportive measures. Positioning patients on their side, providing oxygen by face mask, suctioning secretions and blood carefully, and occasionally performing a jaw thrust to relieve obstruction are usually all that is necessary to prevent hypoxemia and aspiration. Bite

blocks should not be placed in the mouths of seizing patients. They are not indicated and will only serve to increase the likelihood of injury. Attempts to mask ventilate during a seizure are usually ineffective and rarely necessary.

Prolonged Seizure Activity

Although most self-limited seizures do not require intubation, several indications exist for intubation with prolonged seizures. Extensive generalized motor activity will eventually cause hypoxemia, hypotension, acidosis, rhabdomyolysis, hypoglycemia, and hyperthermia. Respiratory depression may result from high doses or combinations of anticonvulsants. Hypoxemia despite supplemental high-flow oxygen is an indication for immediate intubation.

No clear guideline specifically defines the duration of seizure activity requiring intubation. A good rule of thumb is that patients with seizures lasting less than 5 minutes with evidence of hypoxemia (central cyanosis or pulse oximetry readings <90% despite supplemental oxygen and clearly inadequate respirations) or patients with seizures lasting beyond 5 minutes despite appropriate anticonvulsant therapy should be considered for intubation. Generally, when first-line (benzodiazepine) anticonvulsants fail to terminate grand mal seizure activity, rapid sequence intubation (RSI) is indicated. Keppra is often given as a 60 mg/kg up to a maximum dose of 4500 mg IV load to help terminate seizures and can be administered along with benzodiazepines, if time allows. Other second-line anticonvulsants (phenytoin and phenobarbital) require at least 20 minutes for a loading dose; therefore, at the time of initiation, intubation is advisable. The initiation of a propofol or phenobarbital infusion would also be an indication for intubation because of their respiratory depressant effects. Both agents act synergistically with benzodiazepines, increasing the likelihood of apnea and the need for airway management.

TECHNIQUE

RSI is the method of choice in the seizing patient. In addition to its technical superiority, RSI ends all motor activity, allowing the body to begin to correct the metabolic debt. However, cessation of motor activity

while the patient is paralyzed does not represent termination of the seizure, and effective loading doses of appropriate anticonvulsants (ie, Keppra) are required immediately after intubation if not already administered. The recommended technique for the seizure patient is described in **Box 35.2**.

BOX 35.2 RSI for Patients With Prolonged Seizure Activity

Time	Action
Zero minus 10+ min	Preparation
Zero minus 10+ min	Preoxygenation
Zero minus 10+ min	Physiologic optimization
Zero	Paralysis with induction
	Ketamine 1.5 mg/kg *or* etomidate 0.3 mg/kg *or* propofol 1.5-2 mg/kg
	Succinylcholine 1.5 mg/kg
Zero plus 30 sec	Protection and positioning
Zero plus 45 sec	Placement with proof
Zero plus 60 sec	Postintubation management
	Midazolam drip 0.05-0.2 mg/kg/hr IV
	Or
	Propofol drip 1-5 mg/kg/hr IV
	EEG monitoring if patient has ongoing paralysis
	Increased respiratory rate if significant acidosis present

Standard RSI technique is appropriate in the seizing patient with the following modifications:

1. *Preoxygenation*: Preoxygenation may be suboptimal because of uncoordinated respiratory effort; therefore, pulse oximetry is critical. After giving succinylcholine (SCh), the patient may desaturate to less than 90% before complete relaxation and may thus require oxygenation using a bag and mask apparatus and 100% oxygen before

attempts at intubation and continuous passive oxygenation by nasal cannula at 5 to 15 L/min throughout the intubation sequence.

2. *Paralysis with induction:* Etomidate is the primary induction agent if there is associated hypotension. Etomidate may raise the seizure threshold (and therefore inhibit seizure activity) in generalized seizures. Ketamine has been shown to be effective at terminating status epilepticus and at reducing the need for intubation in children. Propofol has also been used as an induction agent in this setting at a dose of 1.5 mg/kg. Few data exist on propofol as an induction agent in patients with seizures. However, there is evidence that it provides rapid suppression of seizure activity after a bolus and infusion and has been used in refractory status epilepticus. Midazolam is an alternative, but the dosage reduction required in a hemodynamically compromised patient means it functions poorly as an induction agent. SCh is recommended for neuromuscular blockade in this setting because of its very short duration of action. An intubating dose of rocuronium will result in paralysis for roughly an hour and will thus prevent the clinician from knowing if there is ongoing seizure activity without continuous electroencephalogram (EEG) monitoring. If sugammadex is available, it could be used to reverse rocuronium as needed and mitigate the concern over prolonged paralysis.
3. *Postintubation management:* There are three additional considerations with respect to postintubation management.

    - Prolonged, deep sedation with an agent that suppresses seizures is desirable for the first hour after intubation to facilitate investigations [eg, computed tomographic (CT) scan] and to allow acidosis to correct with controlled ventilation. Propofol infusion permits rapid reversal of sedation, which allows repeated or ongoing assessment of seizure activity and neurologic status, so often used for this purpose.
    - Long-term neuromuscular blockade should be avoided, if at all possible; however, if it is used, it should be accompanied by adequate doses of a sedation agent and continuous EEG monitoring, if available. If this is not immediately available, motor paralysis should be allowed to wear off before repeat dosing, to evaluate the

effectiveness of anticonvulsant therapy. Effective sedation with a convulsive suppressant such as a propofol or midazolam infusion is preferable to motor paralysis.

- If elevated ICP, head injury, known CNS pathology, or suspected meningitis is present, the elevated ICP intubation technique should be used (see **Box 35.3**).

BOX 35.3 Drugs and Dosages

1. Preintubation seizure management
   - Lorazepam 0.1 mg/kg intravenously (IV) up to 2 mg/min
     or
   - Diazepam 0.1-0.3 mg/kg IV up to 5 mg/min or 0.5 mg/kg/rectum
     or
   - Midazolam 0.1-0.3 mg/kg IV up to 5 mg/min, *then*
   - Fosphenytoin 20 mg/kg (as milligrams of phenytoin equivalent) or
   - Levetiracetam (Keppra) 60 mg/kg up to a maximum of 4500 mg IV load.
2. Induction agents
   - Etomidate 0.3 mg/kg
     or
   - Propofol 1.5-2 mg/kg
     or
   - Ketamine 1.5 mg/kg
3. Neuromuscular blocking agents
   - Succinylcholine 1.5 mg/kg
4. Postintubation sedation and therapy
   - Midazolam 0.05-0.2 mg/kg/hr IV infusion
     or
   - Propofol 1-5 mg/kg/hr IV infusion

Elevated Intracranial Pressure

Elevated ICP poses a direct threat to the viability and function of the brain by limiting blood flow and oxygen delivery. In head trauma, elevated ICP

has been clearly associated with worse outcomes. The problems associated with elevated ICP may be compounded by many of the techniques and drugs used in airway management, because they may cause further elevations of ICP. In addition, victims of multiple traumas may present with hypotension, thus limiting the choice of agents and techniques available. This chapter provides the basis for an understanding of the problems of increased ICP and the optimal methods of airway management in this patient group.

When increased ICP occurs because of an injury or medical catastrophe, the brain's ability to regulate blood flow (autoregulation) over a range of blood pressures is often lost. In general, ICP is maintained through a mean arterial pressure (MAP) range of 80 to 180 mm Hg. Elevation in ICP is often a sign that autoregulation has been lost. In this setting, excessively high or excessively low blood pressure could aggravate brain injury by promoting cerebral edema or ischemia. Hypotension, even for a very brief period, is especially harmful. Hypotension and hypoxia have been shown to be independent predictors of mortality and morbidity in patients with traumatic brain injury (TBI).

CPP is the driving force for blood flow to the brain. It is measured by the difference between MAP and ICP:

CPP = MAP – ICP

It is clear from this formula that excessive decreases in MAP, as might occur during RSI, would decrease CPP and contribute to cerebral ischemia. Conversely, increases in MAP, if not accompanied by equivalent increases in ICP, may be beneficial because of the increase in the driving pressure for oxygenation of brain tissue. It is generally recommended that the ICP be maintained <20 mm Hg, the MAP between 100 and 110 mm Hg, and the CPP near 70 mm Hg. There are a number of confounding elements that may increase ICP during airway management.

Reflex Sympathetic Response to Laryngoscopy

The reflex sympathetic response to laryngoscopy (RSRL) is stimulated by the rich sensory innervation of the supraglottic larynx. Use of the laryngoscope, and particularly the attempted placement of an endotracheal tube, results in a significant afferent discharge that increases sympathetic

activity to the cardiovascular system mediated through direct neuronal activity and release of catecholamines. More prolonged or aggressive attempts at laryngoscopy and intubation result in greater sympathetic nervous system stimulation. This catecholamine surge leads to an increase in heart rate and blood pressure, which significantly enhances cerebral blood flow (CBF) at the apparent expense of the systemic circulation. These hemodynamic changes may contribute to increased ICP, particularly if autoregulation is impaired; therefore, it is desirable to mitigate this RSRL. Gentle intubation techniques (including the use of experienced operators and video laryngoscopy devices) that minimize airway stimulation and pharmacologic adjuncts (eg, β-blockade and synthetic opioids) have been studied to accomplish this mitigation. On balance, the available evidence is insufficient to determine whether pharmacologic adjuncts, in particular fentanyl, has an impact on patient survival or functional neurologic status.

There is little evidence supporting the use of lidocaine to blunt the hemodynamic response to laryngoscopy. As a result, lidocaine is not recommended for the mitigation of the RSRL associated with emergency intubation and should *no longer be administered* for this indication.

Similarly, the short-acting β-blocker esmolol has consistently demonstrated the ability to control both heart rate and blood pressure responses to intubation. However, even a short-acting agent, such as esmolol, may exacerbate hypotension in a trauma patient or confound interpretation of a decrease in the blood pressure immediately following intubation. For these reasons, although esmolol is consistent and reliable for mitigation of RSRL in elective anesthesia, it is generally not used for this purpose for emergency intubation and not recommended.

As mentioned previously, fentanyl at doses of 3 to 5 μg/kg has also been shown to attenuate the RSRL associated with intubation. However, while this approach may mitigate the RSRL, its use adds complexity and increased risk of drug administration errors and *increases* the cognitive load of the clinician performing RSI. As a result, fentanyl is not recommended for routine use in patients with presumed raised ICP but may still have a role in patients with very high MAP and presumed elevated ICP and can be considered on a case-by-case basis. In summary, given the complexity of administering additional medications during RSI, the use of sympatholytic

agents for presumed elevated ICP is controversial and no longer firmly recommended.

ICP Response to Neuromuscular Blockade

SCh itself may be capable of causing a mild and transient increase in ICP, although this claim has also been challenged. This potential threat is minimal, however, and has never been shown to adversely impact patient outcome. SCh, therefore, remains a commonly used neuromuscular blocking agents (NMBA) for management of patients with elevated ICP because of its rapid onset and short duration. Neuromuscular blockade with nondepolarizing agents such as rocuronium is common, and recent registry data suggest nearly half of all emergency RSIs are now performed with rocuronium. At standard intubating doses, 1.5 mg/kg IV, rocuronium creates ideal intubating conditions in 45 to 60 seconds. Because rocuronium does not carry a risk of elevating ICP and is not associated with hyperkalemia, it is a viable option for neuromuscular blockade in brain injury. One important note is that the duration of paralysis with rocuronium is much longer than that with SCh and is dose dependent. If a shorter duration of paralysis is desirable, SCh should be used.

Choice of Induction Agent

When managing the patient with potential brain injury, it is important to choose an induction agent that will not adversely affect CPP. Ideally, one would like to choose an induction agent that can improve or maintain CPP and provide some cerebral protective effect by decreasing the basal metabolic rate of oxygen utilization of the brain ($CMRO_2$). This effect can be likened to decreasing myocardial oxygen demand in the ischemic heart. Etomidate is a short-acting imidazole derivative that exhibits this beneficial cerebroprotective profile with the added benefit of hemodynamic stability. In fact, etomidate is the most hemodynamically stable of all commonly used induction agents. Its ability to decrease $CMRO_2$ and ICP and its hemodynamic stability make it the drug of choice for patients with elevated ICP (see Chapter 21). In the past, ketamine has been avoided in patients with known elevations in ICP because of the belief that it may elevate the ICP further. Several case series in spontaneously breathing patients with

known cerebral spinal fluid (CSF) outflow obstructions, which contained no control groups, formed the basis for this concern. The evidence regarding this phenomenon is mixed, however, and more recent data suggest that ketamine is safe for use in head injury. Ketamine may, in fact, increase cerebral perfusion. In the hypertensive patient, etomidate is preferred owing to the possibility that ketamine can increase MAP.

Device Selection

Several studies have investigated the potential advantages of flexible endoscopic intubation over rigid laryngoscopy, working on the premise that these techniques minimize tracheal stimulation and thus the RSRL. The results of these studies are mixed and do not permit any conclusions recommending one technique over the other. In a controlled operating room setting, the insertion of the endotracheal tube into the trachea is more stimulating than a routine laryngoscopy. It is clear, however, that intubation should be performed in the gentlest manner possible, using video laryngoscopy, limiting both the time and the intensity of the laryngoscopic look.

APPROACH TO THE AIRWAY

RSI is the preferred method for patients with suspected elevated ICP because it provides protection against the reflex responses to laryngoscopy and rises in ICP. The presence of coma should not be interpreted as an indication to proceed without pharmacologic agents or to administer only an NMBA without a sedative induction drug. Although the patient may seem unresponsive, laryngoscopy and intubation will provoke the reflexes described previously if appropriate sympatholytic and induction agents are not used. The sequence in **Box 35.4** is recommended for patients with elevated ICP.

BOX 35.4 RSI for Patients With Presumed Elevated ICP

Time	Action
Zero minus 10+ min	Preparation
Zero minus 10+ min	Preoxygenation

Zero minus 10+ min	Physiologic optimization*
Zero	Paralysis with induction
	Etomidate 0.3 mg/kg or propofol 1.5-2 mg/kg or ketamine 1.5 mg/kg
	Succinylcholine 1.5 mg/kg or rocuronium 1.5 mg/kg
Zero plus 30 sec	Protection and positioning
Zero plus 45 sec	Placement with proof
Zero plus 60 sec	Postintubation management
Propofol drip, 1-5 mg/kg/hr IV	

*Can consider fentanyl at 3 µg/kg IV on case-by-case basis.

INITIATING MECHANICAL VENTILATION

Mechanical ventilation in the patient with elevated ICP should be predicated on three principles: (1) optimal oxygenation, (2) normocapnia, and (3) avoidance of ventilation mechanics (eg, positive end-expiratory pressure, high peak inspiratory pressure) that would increase venous congestion in the brain.

Although there never was a scientific basis for the use of “therapeutic” hyperventilation, it was widely and enthusiastically adopted. The Brain Trauma Foundation Guidelines for the Management of Severe TBI recommend that prophylactic hyperventilation should be avoided and that patients with severe TBI be ventilated in such a way as to target the lower limits of normocapnia ($PaCO_2$ of 35-40 mm Hg). A similar approach seems prudent in patients with medical causes of elevations of ICP (eg, cerebral hemorrhage).

Although there is no outcome evidence supporting its use or demonstrating any benefit, hyperventilation to a $PaCO_2$ of 30 mm Hg may still have a limited role as a temporizing measure in patients demonstrating clinical signs of herniation (blown pupil or decerebrate posturing) unresponsive to appropriate interventions using osmotic agents, cerebrospinal fluid drainage, or both. This should be initiated only with continuous capnography to guide ventilation efforts and avoid harmful sequelae of excessive hypocapnia. In addition, advanced neuromonitoring for cerebral ischemia should be considered. Normal initial physiologic

ventilation parameters are described in Chapter 10. Initial inspired fraction of oxygen (FIO_2) should be 1.0 (100%). FIO_2 can later be decreased according to pulse oximetry, as long as normal oxygen saturations are maintained. Carbon dioxide tension can be followed with arterial blood gases or, preferably, continuous capnography, the first assessment of which should occur approximately 10 minutes after initiation of steady-state mechanical ventilation. To permit early and frequent neurologic examinations, long-term sedation is best accomplished using a propofol infusion, which can be terminated as needed with prompt patient recovery. Deep sedation is desired, however, to permit effective controlled mechanical ventilation and other necessary interventions while mitigating the stimulating effects of the tube in the trachea and eliminating any possibility of the patient coughing or bucking. Propofol is not an analgesic, and an opioid analgesic, such as fentanyl, is used to improve endotracheal tube tolerance and reduce stimulation and responsiveness.

TIPS AND PEARLS

Status Epilepticus

- Even in the difficult airway, RSI is generally preferred for airway management in the actively seizing patient because any technique without neuromuscular blockade is unlikely to succeed. The difficult airway assessment may be challenging. Airway difficulty, therefore, is often a judgment call. Backup plans and appropriate rescue devices should be ready in the event of a failed airway.
- The paralyzed patient may continue to seize, possibly causing neurologic injury despite the lack of motor activity. Administer effective doses of long-acting anticonvulsants, and use benzodiazepines for long-term sedation. Avoid long-term paralysis, if possible. If a long-acting neuromuscular blocking agent is used, arrange continuous EEG monitoring.

Elevated ICP

- RSI is the desired method for tracheal intubation in patients with suspected elevated ICP. The technique allows for control of various

adverse effects and optimal control of ventilation after intubation.

- Etomidate is the preferred induction agent, particularly if the patient is hypotensive.
- Fentanyl is no longer routinely recommended for elevated ICP that is complicated by elevated blood pressure. The additional sympatholytic benefit is likely marginal because most patients will have already received a full induction load as part of RSI. Additionally, no studies have confirmed that it improves patient outcome when used during emergency intubation.

EVIDENCE

Which induction is best for neurocritical patients?

Although lorazepam and diazepam are the prototypical agents for termination of acute seizure activity, they are vastly inferior induction agents. There are no data on the ideal agent as an induction agent in status epilepticus. Etomidate, propofol, and midazolam are all acceptable options. Ketamine has been shown to be effective at terminating status epilepticus, especially in children, and would be a good fourth option.[1-4,6,8]

Midazolam, propofol, or phenobarbital for postintubation therapy in seizure patients?

For postintubation care, the patient should be sedated using a drug that not only provides amnesia and anxiolysis but also optimizes antiepileptic therapy. Benzodiazepines have all these properties and are readily available in the acute care setting. Midazolam is preferred over diazepam and lorazepam as a continuous IV infusion because of its shorter half-life, water solubility, hemodynamic stability, and greater clinical experience in refractory status epilepticus.

Midazolam and propofol are preferred first-line agents, although no prospective randomized trial exists comparing these therapies directly. Despite the popularity of propofol for refractory seizure management in the ICU setting, there is little experience in the emergency setting, and the ICU studies are too small to draw any conclusions.[5-7] The recommended dosing for propofol is 1 to 2 mg/kg IV bolus (or induction), followed by a 1 to 5

mg/kg/hr infusion. Higher sustained doses have been associated with a propofol infusion syndrome. Ketamine has also been studied in the setting for refractory status epilepticus and could be considered as an adjunctive therapy in postintubation management of this patient population.[8] A review of studies utilizing ketamine for this purpose found the average dosage was 2.2 mg/kg/hr as a continuous infusion.

Does physiologic optimization for patients with elevated ICP improve functional outcomes?

It is challenging to make evidence-based recommendations regarding airway management in the patient with a brain injury and elevated ICP, as is the case in many other areas of airway management. Regarding methodology, most studies on the effect of interventions discussed in this chapter were performed on stable patients in the operating room setting; others were performed on deeply anesthetized patients in the intensive care unit during tracheal suctioning. It is difficult to extrapolate the findings in these patient groups to critical patients undergoing emergency intubation. In addition, the timing and dosing of pharmacologic interventions varied significantly, making it difficult to compare one study with another.

There is no study in the literature that compares airway interventions with a functional outcome measure, that is, disability or death. Increases in heart rate, blood pressure, and ICP are the commonly measured parameters comparing one technique or pharmacologic intervention with another because these affect CPP. However, there is no evidence that these are valid surrogates for more meaningful outcome measures such as disability, nor is there evidence that transient elevations in any of the previously mentioned measures have any meaningful impact on morbidity or mortality. Based on the foregoing, there is no evidence that the interventions presented in this chapter do harm, and pending more direct evidence, it does seem intuitive that minimizing adverse changes in ICP, blood pressure, and heart rate would likely contribute to maximizing good outcomes.

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CHAPTER 36

Reactive Airways Disease

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THE CLINICAL CHALLENGE

Airway management in acute asthma or chronic obstructive pulmonary disease (COPD) patients is challenging because intubation will not solve the primary issue: obstruction of the smaller distal airways. Nevertheless, intubation is required when ventilatory failure is likely despite medical and noninvasive respiratory support. Postintubation ventilation may be extremely difficult with persistent or worsening respiratory acidosis, barotrauma, or hypotension caused by high intrathoracic pressures with diminished venous return—albeit more so with asthma than COPD. Thus, the decision to intubate must be made carefully. Aggressively treating acute bronchospasm early to prevent intubation is essential. Noninvasive respiratory support strategies (noninvasive ventilation and high-flow nasal oxygen) may also prevent intubation in many of these patients by reducing the work of breathing until bronchodilators and steroids can take effect.

Initial management of an acute severe asthma exacerbation includes reversal of dynamic bronchospasm using continuous or stacked β_2-agonist nebulization therapy (albuterol 10-15 mg/hr or every 20 minutes) and anticholinergic nebulization therapy (ipratropium bromide 0.5 mg every 20 minutes for three doses). Oral or intravenous (IV) steroids are indicated for the treatment of the inflammatory component. For refractory acute asthma not responding to first-line bronchodilators and corticosteroids, administration of IV magnesium sulfate 2 g in adults or 40 mg/kg (up to a maximum of 2 g) in children reduced the need for admission by 25% and 68%, respectively, in two recent Cochrane reviews (see “Evidence” section). With continued bronchospasm, intramuscular epinephrine or

terbutaline 0.25 to 0.5 mg can provide additional bronchodilation. Early use of noninvasive respiratory support [noninvasive positive-pressure ventilation (NPPV) or high-flow nasal oxygen (HFNO)] may stave off the need for intubation by supporting the work of breathing. Analgesia should be considered in severe cases owing to hyperventilation causing increased air trapping and auto-PEEP (positive end-expiratory pressure). Patients with anxiety may have difficulty tolerating noninvasive support, and mild analgesia can provide anxiolysis and comfort while preparing for intubation. This needs to be performed carefully at the bedside and titrated deliberately with care not to oversedate prematurely. Ketamine, fentanyl, or dexmedetomidine can be used for this purpose.

In COPD, comorbidities (especially cardiovascular disease) play a greater role, and the prognosis (even with short-term mechanical ventilation) is worse. In the patient with COPD, anticholinergic therapy may be as important as β_2-agonist therapy. Steroids are again important to attenuate underlying inflammation. As is the case with many asthma patients, it is progression of fatigue, not worsening bronchospasm, that leads to respiratory failure and arrest. Unless the patient's condition forces early or immediate intubation, a trial of noninvasive respiratory support is recommended because bilevel positive airway pressure (BiPAP) is of proven value in certain COPD patients and may help avoid intubation. HFNO using a heated and humidified high-flow nasal cannula circuit can provide similar reductions in the work of breathing and has been shown to be noninferior to NIPPV. As for the asthmatic patient, mechanical ventilation after intubation in COPD can be difficult to manage. Airway pressures are often high, and breath stacking (causing auto-PEEP) is common, even with excellent ventilator management. Increased intrathoracic pressures induced by mechanical ventilation, combined with volume depletion from the patient's work of breathing before intubation, coexisting cardiovascular disease, and hemodynamic changes related to decreased sympathetic tone after intubation makes the peri-intubation period highly dynamic and unstable. Ventilator management is discussed in the following section.

APPROACH TO THE AIRWAY

Despite this vast array of noninvasive medical treatment modalities, 1% to 3% of acute severe asthma exacerbations will require intubation. These patients are usually fatigued and have reduced functional residual capacity (FRC) and ventilation/perfusion (V/Q) mismatch; so it may be challenging to preoxygenate them optimally, and rapid desaturation must be anticipated. Rapid sequence intubation (RSI), is often the preferred approch if anatomy is advantageous and videolaryngoscopy and intubation is felt to be straightforward. If the patient has a difficult airway, the operator might plan intubation even earlier than for the nondifficult patient so as to have the best conditions and greatest amount of time possible for an awake technique.

Technique

The most important tenet in managing the status asthmaticus patient who requires intubation is to take total control of the airway as expeditiously as possible. Patients typically adopt an upright posture as their respiratory status worsens; this position should be maintained as much as possible during the preintubation period. Preoxygenation should be achieved to the greatest extent possible (see Chapter 8). Noninvasive ventilation may be considered as a means of increasing F_{IO_2} during this phase while decreasing work of breathing. The RSI drugs chosen should be administered with the patient in their position of comfort, often sitting upright. As the patient loses consciousness, the patient should be placed supine with the head of the bed at 20°, the head and neck should be positioned, and laryngoscopy and intubation performed.

Drug Dosing and Administration

Etomidate and ketamine are preferred induction agents in the asthmatic patient. RSI dosing for etomidate and ketamine is 0.3 mg/kg IV and 1.5 mg/kg IV, respectively. Ketamine has a theoretical advantage through its bronchodilator effect, although this is likely negligible if aggressive bronchodilator therapy has occurred. There are no data proving ketamine's superiority in reactive airways disease, and it should be considered to have clinical equipoise with etomidate. In COPD patients with advanced cardiovascular disease, etomidate is preferred to avoid the catecholamine stimulation of ketamine. Other induction agents (such as propofol or

midazolam) are options but may predispose these patients to hypotension in the setting of hypovolemia and increased intrathoracic pressure changes. Neuromuscular blockade with 1.5 mg/kg of either succinylcholine or rocuronium are equally effective. Rocuronium is preferred given its longer duration of action and prevention of initial asynchronous ventilation.

POSTINTUBATION MANAGEMENT

After the patient has been successfully intubated and proper tube position has been confirmed, sedation and analgesia are required to achieve deep sedation for maximal patient-ventilator synchrony. Neuromuscular blockade is typically required during the first few hours of mechanical ventilation to facilitate maximal exhalation time and permissive hypercapnia without dyssynchrony. Intravenous epinephrine drips can be initiated in the most severe cases. Meticulous ventilator management is critical in achieving the best patient outcome. Additional ketamine, as well as continuous in-line albuterol and other pharmacologic adjuncts, can be given.

Mechanical Ventilation

All asthmatic patients have obstructed small airways and dynamic hyperinflation with varying amounts of auto-PEEP (or intrinsic PEEP). Increased auto-PEEP increases the risk of barotrauma, causing pneumothoraces. Safe, uncomplicated alveolar decompression requires prolonged expiratory time, which is achieved by a lower respiratory rate to allow the exhaled air flow to return to baseline between breaths. This may require a rate as low as 8 to 10 breaths per minute in the most extreme cases. Patients can tolerate lung protective tidal volumes, (6-8 mL/kg ideal body weight), but this strategy requires permissive hypercapnia, which results from the combination of low minute and alveolar ventilation and high dead space caused by bronchospasm. Deep sedation and, most commonly, continuous neuromuscular blockade are required to tolerate this strategy and prevent the hypercapnia from stimulating the respiratory center and increasing the respiratory drive.

The measured pressure at peak inspiration is the peak inspiratory pressure and is a measure of airways resistance (including the resistance from the endotracheal tube). This reading has an inconsistent predictive

value for barotrauma or volutrauma (which is better predicted by plateau pressure) and is high in patients with bronchospastic disease or obstructive lung disease. A sudden rise in PIP should be interpreted as indicating tube blockage, mucous plugging, or pneumothorax until proven otherwise. A sudden, dramatic fall in PIP may indicate accidental extubation or esophageal intubation.

The measured intra-alveolar pressure when closing the inspiratory valve at end-inspiration is referred to as the *plateau pressure* (P_{plat}). Values <30 cm H_2O are the best and not usually associated with barotrauma or volutrauma. Measurement and trending of P_{plat} is an excellent objective tool to confirm optimal ventilator settings and the patient's response, as well as the reversal of airflow obstruction. If initial ventilator settings disclose a P_{plat} of more than 30 cm H_2O, consider lowering tidal volume to attenuate hyperinflation.

TIPS AND PEARLS

INITIAL VENTILATOR SETTINGS

- Determine the patient's ideal body weight.
- Set a tidal volume of 6 to 8 mL/kg with FIO_2 of 1.0 (100% oxygen).
- Set a respiratory rate of 8 to 10 breaths per minute.
- Measure and maintain the plateau pressure at <30 cm H_2O.
- Focus on the oxygenation and airway (plateau) pressures initially and allow permissive hypercapnia.
- Ensure continuous sedation and analgesia with propofol or a benzodiazepine along with a nonhistamine-releasing opioid, such as fentanyl.
- Consider paralysis with a long-acting nondepolarizing neuromuscular blocker if it is difficult to achieve ventilation goals.
- Continue in-line β_2-agonist therapy and additional pharmacologic adjunctive treatment based on the severity of the patient's illness and objective response to treatment.

Complications of Mechanical Ventilation

Two of the more common complications seen in mechanically ventilated asthmatic patients are lung injury (baro/volutrauma) and hypotension. Tension pneumothorax should immediately be considered with any episode of hypotension, especially when the onset is sudden. In those patients without tension pneumothorax, hypotension is usually related to either absolute volume depletion or decreased venous return from increasing auto-PEEP and intrathoracic pressure. The inherent risks of developing either one of these complications are directly related to the degree of hyperinflation. Of the two, hypotension is less often attributable to tension pneumothorax but detrimental if missed. Most asthmatic patients will have intravascular volume depletion because of the increased work of breathing, decreased oral intake following the onset of asthma exacerbation, and generalized increased metabolic state. It is appropriate for these reasons to empirically infuse 1 to 2 L of crystalloid either before the initiation of RSI or early during mechanical ventilation.

Pneumothorax can quickly be excluded with bedside ultrasound or a chest x-ray. A test for high intrathoracic pressure causing hypovolemia can also be done with an apnea test after pneumothorax is excluded. The patient is disconnected from the ventilator and allowed to be apneic up to 1 minute as long as adequate oxygenation is ensured by pulse oximetry. In volume depletion, the mean intrathoracic pressure will decline quickly, blood pressure should begin to increase, pulse pressure will widen, and pulse rate will decline within 30 to 60 seconds. With high amounts of auto-PEEP, reductions in air trapping are required as described previously. If auto-PEEP is not an issue, then an empiric volume infusion of 500 mL of crystalloid should be instituted and may be repeated based on the patient's response to the additional volume. If physical examination or radiography fails to identify the culprit lung in a patient that is periarrest, immediate insertion of bilateral chest tubes is indicated. Reassessment of ventilatory pressure settings will be required thereafter. The initial ventilator settings and potential ventilator complications of the asthma patient are shared by the COPD patient.

EVIDENCE

Is emergency department intubation for asthma common, and how is it managed?

A recent analysis of more than 14 500 emergency department intubations for medical indications revealed that only 173 (1.2%) of those were for asthma. In comparison with other intubations, asthma patients were more likely to be preoxygenated with BiPAP (63% vs 14%), undergo RSI (96% vs 81%) and get induced with ketamine (52% vs 12%). Complication rates were similar.[1]

Do inhaled anticholinergics improve outcomes in acute reactive airways disease when compared with inhaled β-agonists alone?

The bronchodilatory effects of anticholinergic agents are well known, but there has been controversy over whether these agents act synergistically with β-agonists in the setting of acute bronchospasm. A recent Cochrane review 2017 concluded that the combined effect of anticholinergics with β-agonists in acute asthma reduced admissions and improved pulmonary function compared with β agonists alone. However, they did have more side effects such as tremor, agitation, and palpitations with combination therapy.[2] In COPD, maintenance anticholinergic agents are helpful; however, in acute exacerbations, it remains unclear. A Cochrane Database review summarized four studies comparing inhaled albuterol with ipratropium bromide in the setting of acute COPD exacerbation. Pooled data from these studies (129 total patients) demonstrated no difference in FEV_1 at 1 hour or 24 hours between the albuterol and ipratropium bromide groups. The addition of ipratropium bromide to albuterol did not yield any benefit over albuterol alone. Despite this relative paucity of evidence, the American Thoracic Society, European Respiratory Society, and the Global Initiative for Chronic Obstructive Lung Disease advocate the use of inhaled ipratropium in acute COPD exacerbations.[3] Thus, based on available evidence, anticholinergic agents should be used in severe acute asthmatic patients as standard therapy and should be considered in the treatment of acute COPD exacerbations, especially when little improvement is seen with β-agonists alone.

Does the use of IV magnesium improve outcomes in patients with acute asthma?

Magnesium plays a role in smooth muscle relaxation, and recent research has focused on the role of this medication in alleviating bronchospasm. In both children and adults, IV magnesium is associated with reduced hospital admissions and improved pulmonary function in both children and adults. In two Cochrane reviews, magnesium prevented admission from 25% in adults to 68% in children.[4,5] There is no good evidence that magnesium decreases the need for intubation. Based on these data, IV magnesium therapy should be considered as adjunctive therapy for severe asthma or in patients unresponsive to initial therapy.

Are there noninvasive ventilatory strategies that may improve attempts at preoxygenation in acute asthma?

Noninvasive positive-pressure ventilation (NIPPV) has been used successfully to decrease the work of breathing and to preoxygenate patients[6]; however, agitation and delirium can confound attempts to preoxygenate in severe cases. A recent multicenter prospective observational study described the technique of *delayed sequence intubation* (DSI), which could be employed in patients whose delirium or agitation prevents optimal preoxygenation via face mask or NIPPV.[7] In DSI, a dissociative dose of ketamine is administered to allow preoxygenation. In this prospective study of 62 patients, mean oxygen saturation increased after DSI (90%-99%), and no adverse effects were noted even in high-risk patients. Although data from this study are promising, lack of randomization, direct comparison to RSI, and small sample size preclude making a recommendation for its routine use.[8]

Is IV ketamine of benefit in acute asthma?

Ketamine has frequently been discussed for management of acute asthma. The theoretical benefit from ketamine's bronchodilator effects, analgesia to slow hyperventilation, and less respiratory drive suppression has driven its use in the emergency department. Its onset of action is rapid, and it can be administered intramuscularly or intravenously. It is accepted as a treatment in severe, refractory asthma of the intubated pediatric patient and some adults without cardiovascular disease. Ketamine has also been proposed for use in nonintubated patients refractory to conventional therapy for treatment, especially in hyperventilating patients and to facilitate

oxygenation with noninvasive ventilation. However, the balance of the dysphoria and increased agitation in a patient in respiratory distress can be detrimental and should be taken into consideration. Ketamine is a logical choice in managing the airway of the severe asthmatic because it increases circulating catecholamines, is a direct smooth muscle dilator, and inhibits vagal outflow. However, there are no controlled studies demonstrating the benefit of IV ketamine in the management of nonintubated asthmatic patients. Case reports of marked improvement in pulmonary function with ketamine have perpetuated its popularity, but no randomized studies have demonstrated ketamine's superiority over other agents. Recently, a double-blind, placebo-controlled study randomized 33 pediatric asthma patients to ketamine infusion (0.2 mg/kg bolus, followed by 0.5 mg/hr for 2 hours) and 35 patients to placebo.[9] Each group also received albuterol, ipratropium bromide, and glucocorticoids. No significant difference in pulmonary index scores (consisting of respiratory rate, wheeze, I/E ratio, accessory muscle use, and oxygen saturation) was found between the two groups. No difference in hospitalization rate was noted. At the present time, based on its mechanism of action and safety profile, ketamine appears to be the best agent available for RSI in the asthmatic. In the absence of ketamine, other agents may be used. There is insufficient evidence to support the use of IV ketamine as adjunctive therapy in nonintubated or ventilated patients.

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CHAPTER 37

Distorted Airways and Acute Upper Airway Obstruction

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THE CLINICAL CHALLENGE

The *upper airway* refers to that portion of the airway anatomy that extends from the lips and nares down to the first tracheal ring. The first portion of the upper airway is redundant: a nasal pathway and an oral pathway. However, at the level of the oropharynx, the two pathways merge, and this redundancy is lost. The most common life-threatening causes of acute upper airway distortion and obstruction occur in the region of this common channel, and they are typically laryngeal. In addition, disorders of the base of the tongue and the pharynx can cause obstruction (**Box 37.1**). This chapter deals with problems that distort or obstruct the upper airway. Foreign bodies in the upper airway are addressed in Chapters 28 and 44.

BOX 37.1 Causes of Upper Airway Obstruction

A. *Infectious*
   a. Viral and bacterial laryngotracheobronchitis (eg, croup)
   b. Parapharyngeal and retropharyngeal abscesses
   c. Lingual tonsillitis (a lingual tonsil is a rare but real congenital anomaly and a well-recognized cause of failed intubation)
   d. Infections, hematomas, or abscesses of the tongue or floor of the mouth (eg, Ludwig angina)
   e. Epiglottitis (also known as supraglottitis)

B. *Neoplastic*
   a. Laryngeal carcinomas
   b. Hypopharyngeal and lingual (tongue) carcinomas
C. *Physical and chemical agents*
   a. Foreign bodies
   b. Thermal injuries (heat and cold)
   c. Caustic injuries (acids and alkalis)
   d. Inhaled toxins
D. *Allergic/idiopathic:* including ACEI-induced angioedema
E. *Traumatic:* blunt and penetrating neck and upper airway trauma

APPROACH TO THE AIRWAY

The signs of upper airway distortion and obstruction may be occult or subtle. Life-threatening deterioration may occur suddenly and unexpectedly. Seemingly innocuous interventions, such as small doses of sedative hypnotic agents to alleviate anxiety or the use of topical local anesthetic agents, may precipitate sudden and total airway obstruction. Rescue devices may not be successful and may even be contraindicated in some circumstances. The goal in patients with upper airway obstruction or distorted upper airway anatomy is to manage the airway in a rapid yet controlled fashion before complete airway obstruction occurs. Until definitive management is attempted, the patient should remain in a position of comfort. This is especially true in children, with whom anxiety, fear, and crying can cause a partial obstruction to become a complete airway obstruction.

When Should an Intervention Be Performed?

Chapter 1 deals with the important question of when to intubate. If airway obstruction is severe, progressive, or imminent, then immediate action (often "*forced-to-act*" rapid sequence intubation [RSI] or cricothyrotomy) is required without further consideration of transferring the patient to another venue (eg, the operating room or another hospital). It is critical to recognize patients who require an inevitable surgical airway and to perform the

procedure without delay, as valuable time is often used up trying other methods to obtain airway control. Failing an indication for an *immediate* intervention, the question becomes more nuanced: What is the expected clinical course?

Penetrating wounds to the neck and airway are notoriously unpredictable (see Chapter 34). Some experts advocate for securing the airway regardless of warning signs, whereas others advocate expectant observation. There are substantial problems with the latter strategy. The first is that the patient often remains relatively asymptomatic until they suddenly and unexpectedly develop total obstruction, resulting in an airway (and patient) that cannot be rescued. The second is that unless a flexible endoscope is used, the observer is able to see only the anterior portion of the airway and not the posterior and inferior parts where the obstruction will likely occur. In other words, when not using a flexible endoscope, one sees only "the tip of the iceberg."

The time course of the airway threat is also important. All other things being equal, a patient who presents with airway swelling, such as angioedema, which has developed over 8 to 12 hours, is at substantially less risk for sudden obstruction than a similar patient where the same degree of swelling has developed over 30 minutes. Overall, for any condition in which the obstruction may be rapidly progressive, silent, and unobservable externally (eg, angioedema, vascular injuries in the neck, and epiglottitis), acting earlier rather than later to secure the airway is the most prudent course.

There are four cardinal signs of acute upper airway obstruction:

- "Hot potato" voice: the muffled voice one often hears in patients with mononucleosis and very large tonsils
- Difficulty in swallowing secretions, either because of pain or obstruction: the patient is typically sitting up, leaning forward, and spitting or drooling secretions
- Stridor
- Dyspnea

The first two signs do not necessarily suggest that total upper airway obstruction is imminent; however, stridor and dyspnea do. The patient

presenting with stridor has already lost at least 50% of the airway caliber and requires immediate intervention. In the case of children younger than 8 to 10 years with croup, medical therapy may suffice. In older children and adults, the presence of stridor may necessitate a surgical airway or, at least, intubation using a double setup. This technique uses an awake attempt from above, ideally using a flexible endoscope, with the capability (prepared in advance) to rapidly move to a surgical airway if needed. Properly performed bag-mask ventilation (BMV) will often be successful in cases with soft tissue obstructions (including laryngospasm) but will generally not overcome a fixed obstruction (such as extrinsic compression of the airway by a hematoma) and, in any case, should not be considered more than just a temporizing maneuver.

What Options Exist if the Airway Deteriorates or Obstruction Occurs?

The key considerations here are as follows:

- **Will rescue BMV be possible?** Will a mask seal be possible to achieve, or is the lower face disrupted? Has a penetrating neck wound entered the airway, rendering it incompetent to high airway pressures? As discussed in Chapter 12, the bag and mask devices most commonly used in resuscitation settings are capable of generating 50 to 100 cm of water pressure in the upper airway, provided that they do not have positive-pressure relief valves and that an adequate mask seal can be obtained. Pediatric and neonatal devices often incorporate positive-pressure relief valves that easily can be deactivated (if needed). This degree of positive pressure is often sufficient to overcome the moderate degree of upper airway obstruction caused by redundant tissue (eg, in the obese), edematous tissue (eg, in angioedema, croup, and epiglottitis), or laryngospasm. However, lesions that are hard and fixed, such as hematomas, abscesses, cancers, and foreign bodies, produce an obstruction that cannot be reliably overcome with BMV, even with high upper airway pressures.
- **Where is the airway problem?** If the lesion is at the level of the face or oro/nasopharynx, and orotracheal intubation is judged to be

impossible (for whatever reason), an extraglottic device (EGD, such as a laryngeal mask airway or King LT) may be considered if there is oral access. If the lesion is at or immediately above the level of the glottis, an EGD may not be effective, and intubation (if the obstruction can be bypassed) or cricothyrotomy (if it cannot) is required. If the lesion is below the vocal cords, cricothyrotomy will not bypass the obstruction, and an entirely different strategy is used (see Chapters 28 and 44).

What Are the Advantages and Risks of an Awake Technique?

In most instances, unless the patient is in crisis or deteriorating rapidly, awake examination using a flexible endoscope is the best approach. The endoscopic examination allows both assessment of the airway and, if indicated, intubation (see Chapters 17 and 24). Alternatively, awake oral laryngoscopy can be performed preferably using a video laryngoscope. If adequate glottic visualization is achieved by direct or video laryngoscopy, intubation is performed. If visualization is suboptimal, but the epiglottis can be seen and is in the midline, orotracheal intubation using RSI is often feasible, especially with a bougie, unless the working diagnosis is a primary laryngeal disorder. On rare occasions, however, the airway may be more difficult to visualize after induction and paralysis or may have deteriorated abruptly between the awake examination and administration of RSI drugs. For these reasons, RSI drugs should be drawn up before the awake laryngoscopy is performed, with intubation often best performed at the time of the initial examination rather than after the delay needed to withdraw the laryngoscope to subsequently perform RSI. If the lesion is suspected to be at the laryngeal level, complete visualization of the larynx, particularly the glottis, is important (eg, flexible endoscopic visualization).

Is RSI Reasonable?

If one is confident that orotracheal intubation is possible and highly confident that the patient can be successfully ventilated using BMV or EGD, then it is reasonable to proceed with RSI (eg, early in the course of a penetrating neck injury). A double setup with readiness for an immediate surgical airway is advisable. The decision to proceed with RSI versus an

awake examination or primary cricothyrotomy is a matter of clinical judgment. A patient with early upper airway injury (eg, inhalation of products of combustion) is often easily intubated via the oral route (absent preexisting difficult airway markers), provided this is done before bleeding from the injury and airway swelling are allowed to progress. The key determinant is the clinician's confidence that intubation will likely succeed and, if not, that oxygenation through BMV or EGD (or by cricothyrotomy) will be timely and successful.

The challenges of patients presenting with upper airway obstruction underscore the importance of possessing alternative airway devices, such as a flexible endoscope and a video laryngoscope, in addition to a conventional laryngoscope and bougie. Patients with upper airway obstructions in whom direct laryngoscopy would likely be impossible, such as severe angioedema, may sometimes be successfully intubated with a narrow profile hyperangulated video laryngoscope (eg, a GlideScope) and are often reasonably straightforward candidates for flexible endoscopic intubation. The decision to attempt hyperangulated blade video laryngoscopy typically depends on the amount of space available to pass the blade. The area between the tongue and the palate can be assessed by visual inspection and palpation, but the base of the tongue and laryngeal areas are impossible to assess until the blade is inserted; therefore, an awake approach is essential (in all but "forced-to-act" scenarios) to determine in a controlled manner if laryngoscopy and endotracheal tube delivery are possible. Both laryngoscopy and endotracheal tube delivery have their own challenges, and the ability to perform successful laryngoscopy may still result in difficult or impossible endotracheal tube delivery. In contrast, flexible endoscopes inserted through the nasopharynx or oropharynx can more easily maneuver around partial obstructions than blades and, with the amount of directional flexibility of the tip of the endoscope, can visualize an obstructed larynx more easily than a blade. Furthermore, endotracheal tube delivery is simplified because it railroads over the endoscope rather than being a separate and distinct delivery.

One approach that has become favored is a dual device technique, in which both a video laryngoscope and flexible endoscope are used. The video laryngoscope blade is used to displace soft tissue and visualize as much of the larynx as possible. If good visualization is obtained and

endotracheal tube delivery is possible, then the patient is intubated. If laryngoscopy or endotracheal tube delivery is difficult, then a separate operator with a flexible endoscope is prepared to perform an endoscopic intubation, which is often even easier when using a video laryngoscope blade to displace soft tissue, open the upper airway, and visualize the approach of the endoscope toward the larynx. Once the endoscope is in the trachea, the endotracheal tube is delivered by railroading down the endoscope, with visualization of the intubation and troubleshooting as needed on the video laryngoscope screen.

TIPS AND PEARLS

- Be reluctant to transfer patients with suspected acute upper airway obstruction and unsecured airways, even short distances. With rare exceptions, it is almost always prudent to secure the airway of a patient with significant acute penetrating neck injury or blunt laryngeal trauma (examples of “dynamic” upper airway obstruction) before transport.
- Angioedema of the upper airway is a potentially dangerous and unpredictable condition, particularly when it has occurred over a short period of time. External examination of the lips, tongue, and pharynx may reveal little of what is going on at the level of the airway. Intervention earlier rather than later is the most prudent course of action. Usually, flexible endoscopy will provide definitive information and serve as a conduit for intubation, if indicated.
- The patient with acute upper airway obstruction, a disrupted airway, or a distorted airway who *can* protect and maintain the airway and *can* maintain oxygenation and ventilation should always be considered as having a *difficult airway*, and the difficult airway algorithm (Chapter 5) should be used.
- The patient with upper airway obstruction, a disrupted airway, or a distorted airway who *cannot* maintain oxygenation or ventilation should be considered as having a *failed airway*, and the failed airway algorithm (Chapter 4) should be used.

- Blind airway management techniques (eg, blind nasotracheal intubation) in patients with upper airway obstruction or distorted anatomy are contraindicated and should not be attempted.
- BMV alone cannot be relied on to rescue an airway, particularly if the obstruction is caused by a fixed lesion.
- RSI is usually contraindicated unless the operator is forced to attempt a "one-best-shot" intubation attempt invoking the *forced-to-act* principle (see Chapter 5), the awake look is reassuring, or the operator judges that RSI is likely to be successful and a backup plan (double setup) is in place.
- Be prepared for a cricothyrotomy before performing an awake laryngoscopy, recognizing that manipulation of an irritated upper airway, administration of a sedative agent, or application of a topical anesthetic may precipitate total obstruction.

EVIDENCE

What evidence guides emergency management of patients with acute upper airway obstruction, and how often are awake techniques used?

A recent report from the National Emergency Airway Registry (NEAR) revealed that approximately 1% of all adult emergency airway encounters are managed with a flexible endoscope, most often employed in the setting of airway obstruction.[1] In a more recent NEAR analysis of 19 071 discrete patient encounters, an awake technique was used on the first attempt in 82 (0.4%) patients. Most first attempts (91%) were performed by emergency medicine physicians for angioedema (32%) and nonangioedema airway obstruction (31%). The most common initial device used was a flexible endoscope (78%). Among all awake intubations, first-attempt success was achieved in 85% (95% CI [76%-95%]).[2]

How commonly does angiotensin-converting enzyme inhibitor (ACEI)–induced angioedema require intubation, and how is it managed?

In the same NEAR cohort, intubation was performed for angioedema in 98 cases (0.5%). First-attempt success was achieved in 81%, with emergency physicians performing the procedure in 94% of encounters. The most

common device used was a flexible endoscope (49%), and 42% of attempts were via a nasal route. Pharmacologic methods included sedation with paralysis (61%—likely those intubated early on their course), topical anesthesia with or without sedation (13% and 13%, respectively), and sedation only (10%). Among 19 (19%) patients requiring additional attempts, intubation was achieved at the second attempt in 10 (53%). Cricothyrotomy occurred in two patients (2%), but no deaths were observed.[3]

Is it true that application of topical anesthetic agents to a distorted airway can trigger total airway obstruction?

There are no studies related to this topic, but most experienced airway managers have seen it. Although the mechanism by which this occurs is a matter of speculation, it is a real phenomenon, and caution should be exercised in the setting of preexisting airway obstruction when topical anesthesia and instrumentation of the airway is contemplated. Plan rescue strategies in advance and examine the airway in a setting where quick rescue can be executed if complete obstruction occurs.

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CHAPTER 38

The Pregnant Patient

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THE CLINICAL CHALLENGE

The physiologic and anatomic changes associated with pregnancy may pose challenges to all facets of airway management, including oxygenation, ventilation, and securing the airway. Along with many physiologic changes, late-term pregnancy also presents unique difficulties related to the airway. In fact, complications related to airway management in the parturient patient are the most significant cause of anesthetic-related maternal mortality. Pregnancy changes the patient's anatomy and physiology in a variety of distinct ways:

- *Oxygen reserve and depletion:* There is an approximately 20% reduction in expiratory reserve volume (ERV), residual volume (RV), and functional residual capacity (FRC) and an increased maternal basal metabolic rate and oxygen demand by the fetal unit. These changes lead to more rapid desaturation during apnea even when fully preoxygenated (approximately 3 minutes compared to 6 to 8 minutes in a nonpregnant adult) and are further exacerbated in the obese pregnant patient.
- *Physiologic hyperventilation:* Progesterone increases the ventilatory drive and leads to hyperventilation. Maternal minute ventilation increases early in pregnancy largely because of an increase in tidal volume. This results in alteration of "normal" blood gas parameters, which must be considered when managing mechanical ventilation. Maternal $PaCO_2$ falls to approximately 32 mm Hg, which is associated with a compensatory decrease in bicarbonate from 26 to 22 mEq/L in

order to maintain a normal maternal pH. Mechanical ventilation must provide some degree of hyperventilation in order to maintain maternal pH. A reasonable approach is to increase the minute ventilation by approximately 20% for the pregnant woman in the first trimester, increasing to 40% by term.

- *Cardiopulmonary compromise in late pregnancy:* In the late stages of pregnancy, when the patient is placed supine, the effects of the gravid uterus on the diaphragm and, occasionally, increased breast size on the chest wall further decrease the FRC. In addition to decreasing FRC, supine positioning in the late second and third trimesters of pregnancy can result in aortocaval compression by the gravid uterus. This significantly reduces blood return to the heart, impairing maternal and fetal perfusion. This can be mitigated to a certain degree by placing the patient in the left lateral decubitus position.
- *Effects on laryngoscopy and bag-mask ventilation (BMV):* Pregnancy can also affect laryngoscopy and BMV. Weight gain, greater resistance to chest expansion by abdominal contents, and increased breast size may make BMV difficult in a manner analogous to that seen with an obese patient. Enlarged breast size can also make insertion of a standard laryngoscope more difficult. The effects of estrogen and increased blood volume contribute to mucosal edema of the nasal passages and pharynx, causing airway tissues to become redundant, friable, and more prone to bleeding, especially with airway manipulation. This mucosal edema can also lead to dynamic distortion of the airway structures and difficulty both in identifying structures and in passing the endotracheal tube through the upper airway to the glottis. This upper airway distortion can be worsened by preeclampsia, active labor with pushing, and the infusion of large volumes of crystalloid fluids. Vascular engorgement also leads to a decrease in luminal size in the trachea, requiring a smaller than expected endotracheal tube (average size: 6.5-7 mm). In addition, BMV is more challenging owing to engorged upper airway tissues.
- *Increased propensity for aspiration:* As pregnancy progresses, gastric acid secretion increases, causing a decrease in maternal gastric pH, as well as an increase in gastrin levels, a reduction in gastric activity, and

an increase in gastric emptying time that can result in an increase in resting gastric volume. Enlargement of the uterus increases the pressure exerted on the stomach, which, combined with a reduction in gastroesophageal sphincter tone in pregnancy, increases the risk of reflux. A “full stomach” should always be assumed in these patients. Administration of neuromuscular blockade will exacerbate this further by causing a loss of supporting abdominal muscle tone. These normal changes in gastrointestinal physiology start early in the second trimester but become most problematic in the mid- to late second and third trimesters.

- *Effects on neuromuscular blocking agents:* Maternal plasma cholinesterase activity is reduced by 25%; however, this does not result in any significant effects on elimination, half-life, or duration of effect of succinylcholine. Pregnancy, however, does result in enhanced sensitivity to the aminosteroid muscle relaxants, such as vecuronium and rocuronium, which may prolong their effects.

APPROACH TO THE AIRWAY

In early pregnancy, fluid and FRC changes predominate, but the airway itself is unchanged. As pregnancy progresses, difficulty in both intubation and BMV should be anticipated. Nevertheless, the approach to airway management in the pregnant patient is no different from that of any other emergent intubation, except for consideration of the unique features of pregnancy described in The Clinical Challenge section, which may create airway difficulty beyond the sixth month of pregnancy.

Key issues to consider for airway management in these patients are as follows:

- Anatomically, think of the third trimester pregnant patient as analogous to an obese patient, and use the difficult airway algorithm. If careful assessment using the LEMON, ROMAN, RODS, and SMART mnemonics (see Chapters 2 and 5) indicates that rapid sequence intubation (RSI) is reasonable, have backup devices (eg, extraglottic device) readily at hand, and anticipate more rapid oxyhemoglobin desaturation than for the nonpregnant patient.

- If flexible endoscopic intubation is the chosen method, avoid the nasal route in favor of the oral route unless anatomic abnormalities preclude orotracheal intubation. The mucosa may be engorged, edematous, and friable, and nasotracheal intubation is more likely to lead to mucosal damage and bleeding.
- Preoxygenate fully, using a minimum of 3 minutes of breathing 100% oxygen or eight vital capacity (VC) breaths; as FRC is reduced, oxygen consumption is increased, and apnea leads to desaturation more rapidly. This is best provided with the patient in an upright position while passively breathing through a non-rebreather (NRB) face mask with oxygen delivered at the “flush rate” (see Chapter 8) of 40 to 70 L/min. Passive oxygenation during the apneic phase, using nasal cannula at 5 to 15 L/min, should be used routinely, if possible, to delay desaturation during attempts at intubation.
- All opioids and induction agents may reduce maternal blood flow to the placenta and, therefore, blood flow to the fetus. These agents also cross the placental barrier. Because muscle relaxants are fully ionized quaternary ammonium salts, they do not readily cross the placenta. Antihypertensive agents, such as metoprolol, labetalol, and esmolol, cross the placenta and carry a risk of inducing fetal bradycardia. In the context of emergent airway management, however, maternal well-being supersedes the potential for fetal exposure. When these agents are administered and delivery of the fetus is imminent, the caregiver charged with the management of the neonate immediately after delivery should be fully briefed regarding the agents administered to the mother.
- Although there is no hard evidence to support the routine use of cricoid pressure, it may be more relevant in pregnant patients because of the gastrointestinal changes described previously. We consider the maneuver optional, but if it is to be used, the person tasked with applying it should be trained and skilled in the application of cricoid pressure and be ready to release it early if any difficulty is encountered.
- Although rescue airway devices, such as the laryngeal mask airway (LMA), intubating LMA, iGel, and the King laryngeal tube, may be

used in the event of a failed intubation similar to the case of the nonpregnant patient, the enhanced risk of aspiration in the nonfasted pregnant patient creates additional urgency for definitive airway control. Successful placement of one of these extraglottic rescue devices may achieve adequate gas exchange, giving the provider additional time to secure a definitive airway and avoid a surgical airway. Nonetheless, as the term pregnant patient may rapidly desaturate, do not delay cricothyrotomy when intubation fails and adequate oxygenation cannot be maintained using a bag and mask or an extraglottic device (EGD).

Recommended Intubation Sequence

Preparation

Perform a detailed difficult airway examination, including LEMON, ROMAN, RODS, and SMART, before deciding the appropriateness of RSI. Even if other markers of difficult laryngoscopy are not present, obesity, enlarged breasts, and physiologic airway edema can complicate intubation. By default, even without typical predictors of a difficult airway, the difficult airway algorithm should be used for patients in late-term pregnancy. As with the nonpregnant patient, if the intubator does not have confidence that oxygenation (by BMV or EGD) and intubation will be successful, an awake technique with topical anesthesia should be employed (see Chapter 5). Assemble your airway equipment both for immediate management and for potential rescue of a failed airway. Be sure to include a selection of smaller-sized endotracheal tubes with stylets loaded, a bougie, a short-handled laryngoscope (large breast size often inhibits use of a standard-length laryngoscope handle), a rescue device with which you are familiar, and equipment to perform a surgical airway.

Preoxygenation

Preoxygenate fully using a minimum of 3 minutes of tidal breathing with 100% oxygen (see earlier). Preoxygenation is ideally performed in the upright position; however, if the patient is supine, use left lateral decubitus positioning when in the supine position to avoid aortocaval compression.

Tilting the abdomen slightly to the left with a wedge or pillow under the right hip displaces the gravid uterus from the inferior vena cava.

Physiologic Optimization

Similar to the nonpregnant patient, ensure optimal hemodynamics with fluid resuscitation and blood, if indicated. Hypotensive patients in late pregnancy should be placed in the left lateral decubitus position. Hypertensive emergencies should be treated primarily with magnesium sulfate.

Paralysis With Sedation

Paralytic agent selection is similar to that for the nonpregnant patient. Unless contraindicated, succinylcholine is recommended for paralysis at a dose of 1.5 mg/kg. If succinylcholine is contraindicated, a nondepolarizing agent, ideally rocuronium 1.5 mg/kg, should be administered, despite the risk of prolonged effect after administration. The choice of induction agent is dictated by maternal hemodynamic condition, as in the nonpregnant patient. There is no evidence to support the use or avoidance of any induction agent in pregnancy, although ketamine would be a second-line choice if intubation were required in the setting of severe preeclampsia or eclampsia.

Positioning

Intubation success can be significantly enhanced with proper positioning before administration of induction agents. For the obese parturient patient or one with excessive breast tissue, placing a roll or a pillow vertically between the shoulder blades moves the glottic structures forward and assists in displacing the breasts away from the neck. Positioning of the occiput is equally important because too much extension of the neck can move the glottic structures anteriorly and impede visualization. Placing a pad or folded sheet under the patient’s head to bring it into a neutral position may eliminate this. A head up position (20°-30°) can help with ventilation both in the spontaneously breathing patient and when positive pressure ventilation is required. Cricoid pressure may, intuitively, be more important in the pregnant patient, but evidence supporting its routine use is scant. If cricoid pressure is used and glottic visualization is difficult, release the

glottic pressure to improve glottic view, and allow the intubator to perform external laryngeal manipulation.

Placement With Proof

As with the nonpregnant patient, tube placement must be confirmed by detection of end-tidal carbon dioxide in addition to physical examination, no matter how certain the operator is that the trachea has been successfully intubated.

Postintubation Management

There are no widely adopted guidelines on mechanical ventilation parameters in pregnancy; however, we can glean some guidance from the physiologic changes in pregnancy. Pregnancy is associated with an increased metabolic rate, which requires increasing minute ventilation as the pregnancy progresses. At term, this translates into a 30% to 50% increase in minute ventilation. Arterial blood gases or pulse oximetry and end-tidal carbon dioxide monitoring will aid in adjusting the ventilation parameters. Although a pregnant patient with ARDS should follow low tidal volume ventilation parameters, modest adjustments of both rate (start at 12-14 per minute) and tidal volume (up to 12 mL/kg) may be required to meet ventilatory needs. This should be done while monitoring the plateau pressure to make sure it stays <27 cm H_2O. If ventilation pressures are high, placing the patient in reverse Trendelenburg and left lateral decubitus position to move the abdominal contents down off the diaphragm may bring some improvement. In addition, tidal volume can be reduced somewhat and the respiratory rate increased.

Management of the Failed Intubation

As with any patient for whom emergent intubation is required, unanticipated difficulty can be encountered despite a careful difficult airway assessment. In the pregnant patient, the approach needs to be modified slightly to accommodate the anticipated physiologic changes imposed by pregnancy. Primarily, this is driven by the rapidity with which the mother desaturates and the commonly encountered airway edema and friability. We recommend reducing the number of attempts at laryngoscopy before

moving to the failed airway algorithm. Even though maintaining oxygenation and ventilation is important for all patients, it is paramount in the pregnant patient, who has reduced physiologic reserve. In this circumstance, choose an EGD with which he or she is most facile and has the most experience. Properly performed, two-handed, two-person BMV may buy time to allow an alternative to cricothyrotomy. Nevertheless, one needs to be prepared to perform a surgical airway if the EGD is not able to provide adequate oxygenation and ventilation. Keep in mind that dynamic upper airway edema, which may develop quickly, is a common cause of inability to both visualize the glottic structures and ventilate with BMV or EGDs. Resistance to diaphragmatic excursion by the uterus and the weight of the gravid breast on the chest will diminish the patient's FRC and impede successful ventilation, which may be mitigated by placing the patient in a reverse Trendelenburg position, causing the abdominal contents to shift caudally.

SUMMARY

Late-term pregnancy induces changes that affect almost every aspect of airway management. Classification of the late-term pregnant patient as a difficult airway, use of the difficult airway algorithm, and consideration of rapid oxyhemoglobin desaturation and the technical challenges of laryngoscopy and BMV will help the operator develop a cogent plan, including rescue from intubation failure.

TIPS AND PEARLS

- Proper positioning of the pregnant patient, including placing the head slightly up with a roll between the shoulders, and good support under the occiput before induction and attempting intubation may improve visualization and intubation success.
- Anticipate rapid desaturation. Robust preoxygenation using flush rate oxygen through an NRB mask and apneic nasal oxygen, during RSI, will prolong the period of safe apnea.

- Supraglottic edema is a common cause of intubation failure; therefore, a smaller (6.5-7 mm) endotracheal tube may be required.
- Video laryngoscopy offers substantial advantages for glottic visualization and intubation when compared with direct laryngoscopy and is the first-line device.
- As for the nonpregnant patient, cricoid pressure is optional but may be more relevant if the risk of aspiration is deemed to be high. In the event of difficult laryngoscopy or a failed airway requiring an EGD placement, releasing cricoid pressure early may improve glottic visualization and intubation.
- When choosing pharmacologic agents to facilitate intubation, the general rule of thumb is "if it benefits the mother in the acute setting, it will ultimately benefit the fetus."

EVIDENCE

What physiologic abnormalities make emergency airway management more challenging in the pregnant patient?

Maternal morbidity and mortality from anesthesia is on the decline; however, when there are poor outcomes in maternal anesthesia, airway issues are the most prevalent.[1] The physiologic differences of the maternal airway include hormonal effects on the mucosa, dynamically changing upper airway edema, especially on the verge of delivery, increased risk of gastrointestinal reflux and aspiration, increased minute ventilation, decreased total lung capacity, decreased FRC, and increased tidal volume.[1–7] There is debate about whether the maternal airway is truly more anatomically difficult.[1] Because obstetric airway emergencies are rare but devastating, a recent review strongly advocates that providers practice and prepare for the possibility of the failed airway in obstetrics.[4] Physiologic changes of pregnancy also affect mechanical ventilation, and goals include keeping peak inspiratory pressure <35 cm H_2O and plateau pressure <27 cm H_2O.[6]

Does apneic oxygenation improve safe apnea time in pregnancy?

One simulator study showed that using nasal cannula apneic oxygenation for 3 minutes with 100% F_{IO_2} during RSI increased the time to desaturation.[3] The Obstetric Anaesthetists' Association and Difficult Airway Society guidelines for the management of difficult and failed tracheal intubation in obstetrics in 2015 also advocate for nasal oxygen and mask ventilation immediately after induction in their algorithms.[5]

Which EGD is best for the pregnant patient?

EGDs have been studied more extensively in low-risk, elective cesarean deliveries, and no published trials have directly compared endotracheal intubation with EGDs for ED intubation.[8,9] A systematic review and meta-analysis of airway management in elective cesarean deliveries found five studies comparing first attempt success rate in EGD device placement (LMA Classic, LMA Supreme, LMA ProSeal, and iGel) and endotracheal intubation. This showed no difference in first attempt success rate between these methods. However, a sensitivity analysis for the iGel subgroup showed a significantly higher first attempt success rate (OR = 3.95, 95% CI, 1.09-14.25; I_2 = 0%; P = .04) and significantly reduced incidence of difficult placement (OR = 0.07; 95% CI, 0.01-0.54; P = .01).[10,11] In this same review, seven studies evaluated time to device insertion, and there was a statistically significant shorter time to EGD device insertion compared with intubation of −15.8 seconds. When only the higher quality randomized controlled trials (RCTs) were evaluated, this statistically significant difference was no longer present and dropped to −7.44 seconds.

Smaller studies performed on pregnant patients involving EGDs have occurred in the setting of failed intubation, focusing on their use as rescue devices. EGDs were found to be effective rescue tools in avoiding the complications that occur with further intubation attempts such as hypoxemia, aspiration, and airway trauma.[12]

None of these devices protect against aspiration, but the anatomic and physiologic changes of pregnancy make aspiration a significant concern. Second- and third-generation EGDs (LMA Supreme, LMA ProSeal, iGel, King laryngeal tube, AuraGain) include a second lumen for passing an orogastric tube to decompress the stomach. The increased seal pressure of the LMA ProSeal (~32 cm H_2O) and the iGel (24-26 cm H_2O) allows for

higher ventilatory pressures, a finding constant across a wide range of body mass index scores. Compared with a classic LMA, these features are advantageous in the pregnant population. Based on limited data, in pregnant patients, it appears that the iGel, an EGD made of preformed medical-grade thermoplastic elastomer and designed to anatomically mirror the periglottic structures, has some advantages over its LMA counterparts.[13] Nonetheless, the choice of rescue device should be influenced by operator experience and device availability.

What is the rate of failed intubations in obstetrics, and has it improved with recent advances in difficult airway management?

There is variability and controversy, in anesthesia literature, regarding the rate of failed intubations in the pregnant patient, but a review of the literature dating back to 1970 found the incidence to be 1 in 390.[14] This same review states that for every 60 failed intubations there will be one maternal death. Several studies have found these rates to be declining, with the overall rate of general anesthesia in obstetrics decreasing over time.[15–17] Several studies of obstetric anesthesia claims for injuries also found improved safety, with a decrease in respiratory complications from 24% to 4% and a decrease in claims from inadequate oxygenation/ventilation or aspiration of gastric contents and esophageal intubations.[16,17] A third study found the rate of difficult intubations in a 20-year cohort analysis of 2633 patients to be 4.7% and that of failed intubations to be 0.8%, and these rates remained stable over the 20 years reviewed.[18] These studies suggest that significant risks are associated with airway management in obstetric patients and that these rates have been stable or declining in incidence. One recent retrospective study evaluated 180 obstetric intubations over a 3-year period and found 157 of 163 direct laryngoscopy intubations and 18 of 18 video laryngoscopy intubations were successful in the first attempt. The one failed direct laryngoscopy intubation was rescued using a video laryngoscope.[19] It is highly recommended to anticipate and recognize the difficult airway in pregnancy and to follow difficult airway algorithms with a few well-chosen devices, considering the anatomic and physiologic changes occurring in pregnancy. It is also recommended to maintain ongoing training and education in this area.[5,20]

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CHAPTER 39

Cardiovascular Emergencies

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THE CLINICAL CHALLENGE

Critically ill patients present to the emergency department (ED) every day, but those having a hypertensive or cardiovascular emergency are a special subset with unique challenges relating to maintaining tissue perfusion and oxygen delivery. These patients may present with hyperdynamic congestive heart failure or congestive heart failure with cardiogenic shock, ischemic cardiac disease (acute coronary syndrome), or aortic dissection. During airway management, attention must be paid to hemodynamics with a keen focus on avoiding significant changes in heart rate and blood pressure, which could deleteriously affect cardiac output, myocardial oxygen supply, and demand, as well as vascular sheer forces. There is a fine line that practitioners must walk to provide optimal drug dosing in these patients. During emergency airway management, one endeavors to mitigate pain, induce hypnosis, blunt the reflex sympathetic response to laryngoscopy (RSRL), and provide appropriate induction medication dosing to achieve good intubating conditions without producing postintubation hypotension (PIH) and diminished coronary perfusion.

Independently of drug effects, those individuals with congestive heart failure are more prone to develop PIH owing to a combination of the diminished preload commensurate with a transition to positive pressure ventilation, relief of high sympathetic tone as work of breathing is offloaded along with relative hypocarbia.

Reflex Sympathetic Response to Laryngoscopy

The RSRL is stimulated by the rich sensory innervation of the supraglottic larynx. Use of the laryngoscope, and particularly the attempted placement of an endotracheal tube stimulates pain receptors, resulting in an increase in sympathetic activity to the cardiovascular system mediated through direct neuronal activity and release of catecholamines. More prolonged or aggressive attempts at laryngoscopy and intubation result in greater sympathetic nervous system stimulation. This catecholamine surge leads to increased heart rate and blood pressure, which increase myocardial oxygen demand. In patients with ischemic heart disease, this can potentiate or worsen myocardial ischemia. Therefore, it is desirable to mitigate this RSRL. Gentle intubation techniques (including the use of experienced operators and video laryngoscopy devices) that minimize airway stimulation and pharmacologic adjuncts (eg, β-blockade and synthetic opioids) have been studied to accomplish this mitigation.

The short-acting β-blocker esmolol has consistently demonstrated the ability to control both heart rate and blood pressure responses to intubation. A dose of 2 mg/kg given 3 minutes before intubation is commonly used. Unfortunately, administration of β-blocking agents in emergency situations may be problematic for several reasons. Even a short-acting agent, such as esmolol, may exacerbate hypotension or confound interpretation of a decrease in the blood pressure immediately following intubation. Although esmolol is consistent and reliable for mitigation of RSRL in elective anesthesia, it should not be used in emergency intubation.

Fentanyl at doses of 3 to 5 µg/kg has also been shown to attenuate the RSRL associated with intubation in the OR. There are no data that prove an outcome benefit from opiate sympatholysis during emergency rapid sequence intubation (RSI), even in patients with elevated blood pressure who are suffering from a cardio or neurovascular catastrophe. In addition, patients undergoing RSI will have received near general anesthetic levels of a sedative-induction agent that, theoretically, would already work toward mitigating the sympathetic surge associated with laryngoscopy. Any possible benefit from fentanyl would need to be weighed against the additional time needed to administer and the possibility of a drug dosing error. For these reasons, *routine* sympatholysis is not recommended for emergency RSI of the hypertensive patient; however, it is reasonable to consider it on a case-by-case basis for patients who may be intolerant to

spikes in heart rate, blood pressure, or vascular shear forces. This will ultimately depend on all the available clinical information and provider judgment. If undertaken, the recommended dose of fentanyl is 3 µg/kg and should be administered as a single dose over 60 seconds. This technique permits effective mitigation of the RSRL, with greatly reduced chances of apnea or hypoventilation before sedation and paralysis (see Chapter 20). Fentanyl should not be administered to patients with incipient or actual hypotension or to those who are dependent on sympathetic drive to maintain an adequate blood pressure for cardiac perfusion. In such cases, the ensuing hypotension may cause further myocardial ischemia.

Intubation should be performed in the gentlest manner possible, limiting both the time and intensity of laryngoscopy. Several studies have investigated the potential advantages of flexible endoscopic intubation over direct laryngoscopy (DL), working on the premise that these techniques minimize tracheal stimulation and thus the RSRL. Results of these studies are mixed, and there is no clear clinical benefit of one modality over another. In a controlled operating room setting, the insertion of the endotracheal tube into the trachea is more stimulating than a routine laryngoscopy.

Choice of Induction Agent

When managing the patient with ischemic cardiac disease, it is important to choose an induction agent that will not increase myocardial oxygen demand and cause myocardial ischemia.

Ketamine stimulates the sympathetic nervous system centrally by decreasing catecholamine reuptake. Via sympathetic nervous system stimulation, ketamine typically produces a 20% increase in heart rate and a 25 mm Hg increase in blood pressure, which can produce myocardial ischemia and should be avoided in patients with severe ischemic cardiac disease. It may be reasonable to use ketamine when a patient is experiencing bradycardia and hypotension, because its sympathetic stimulation may benefit the patient in this scenario. However, it is also important to remember in such a patient that their endogenous catecholamines may already be depleted, and in this scenario, ketamine

could act only as a direct myocardial depressant and negative inotrope, leading to worsening patient blood pressure and hemodynamics.

Etomidate is the most hemodynamically stable of all commonly used induction agents and is the drug of choice for most emergency RSIs, particularly in patients experiencing cardiovascular emergencies. It is a short-acting imidazole derivative, which is an induction agent that acts on the GABA receptors via a different receptor than propofol and barbiturates. Although etomidate has minimal cardiovascular effects at usual doses, it is recommended to consider using decreased doses (0.15-0.2 mg/kg) guided by patient age and vital signs at the time of intubation.

Choice of Paralytic Agent

Succinylcholine (dose: 1.5 mg/kg IV) is a membrane depolarizing paralytic agent that binds to neuromuscular receptors similar to acetylcholine but remains bound longer than acetylcholine and produces muscle fasciculation, followed by relaxation within 1 minute and paralysis for 5 to 10 minutes. It can cause a transient increase in serum potassium by 0.5 to 1.0 mEq/L that in most patients is clinically insignificant. However, in those with preexisting neuromuscular disorders complicated by muscle wasting, there may be postsynaptic upregulation that places them at risk for life-threatening hyperkalemia (see Chapter 22). Succinylcholine, particularly after repeat dosing, can also cause bradydysrhythmias. Thus, even when patients are tachycardic, it is prudent to have atropine nearby prior to administering a second dose of succinylcholine in the event that significant bradycardia occurs.

Rocuronium (1.5 mg/kg) is a nondepolarizing neuromuscular blocker that competitively antagonizes acetylcholine at the neuromuscular junction, blocking the binding of acetylcholine. Given in doses >1 mg/kg, rocuronium has a similar onset and produces intubating conditions comparable to succinylcholine. However, escalating doses of rocuronium improve first-attempt success, with maximal benefit observed at doses >1.4 mg/kg, particularly if DL is used (see Chapter 22). This is the basis for the new recommendation of 1.5 mg/kg of rocuronium for emergency RSI. It does not exhibit any cardiac effects. Rocuronium does produce an extensive clinical paralysis that can last >1 hour but avoids the need to consider the

multitude of contraindications and precautions that must be factored into succinylcholine use. Sugammadex, a rapid rocuronium reversal agent, dissociates rocuronium molecules from the acetylcholine receptor and reverses neuromuscular blockade within 2 minutes.

APPROACH TO THE AIRWAY

Despite the potential adverse hemodynamic effects that come with laryngeal manipulation during intubation in the setting of ischemic heart disease, there is no evidence that direct or video laryngoscopy causes worse outcomes in patients intubated in the context of a hypertensive emergency. However, VL is proven to be a more successful tool in ED patients and should be the default device in the hypertensive patient as well. RSI is recommended for most patients requiring emergency intubation while experiencing a hypertensive or cardiovascular emergency unless coexisting anatomic or physiologic difficulty mandates that an awake technique be used.

Recommended Intubation Sequence

Preparation—If available, cardiac and thoracic ultrasound should be performed to determine the global cardiac function (ejection fraction, identify obvious wall motion abnormalities) and presence/absence of pulmonary edema. This will help identify patients who are more likely to develop vital sign instability and PIH or arrest peri-intubation in order to specifically inform drug choice and dose adjustment.

Preoxygenation—In patients presenting with pulmonary edema, preoxygenation is crucial. If available, the optimal method to preoxygenate is noninvasive positive pressure ventilation or high flow nasal cannula (humidified and warmed oxygen delivered at up to 60 L/min).

Physiologic Optimization—Any patient with a history of hypertension presenting with a low-normal blood pressure and tachycardia should be approached carefully because these may predict cardiovascular collapse. As mentioned previously, sympatholysis is optional and not routinely recommended. However, for extreme cases of hypertensive emergency, fentanyl, at a dose of 3 μg/kg, can be given to further mitigate the heart rate and blood pressure response to laryngoscopy and intubation. Pretreatment

with esmolol is not recommended owing to the risk of cardiovascular collapse.

Paralysis With Sedation—No dose reduction should be used with the muscle relaxant; rather, in the cardiac patient in shock, a 25% higher dose of neuromuscular blocking agent should be used in view of a low-flow state. However, significant dose reduction of sedation is almost always needed in this group of patients owing to the precarious state of the circulation and the hypotensive effect that all sedatives will exert in these circumstances.

Positioning—This group of patients rarely tolerate lying flat prior to induction, and thus the above steps should be undertaken with the patient sitting at at least 30° upright. Once consciousness is lost, rapid positioning of the patient in the optimum intubating position should be a priority.

Placement With Proof—PIH may be accompanied by a reduction in CO_2 output, which may impair qualitative CO_2 devices. The use of an in-line end-tidal quantitative CO_2 monitor is recommended.

INITIATING MECHANICAL VENTILATION

Take care when delivering positive pressure ventilation to patients with cardiogenic shock. Prolonged or high pressures may lead to decreased preload, cause reduced cardiac output, and potentiate PIH. A dynamic balance of ventilation pattern and flows is required to deliver effective ventilation in this challenging group of patients.

TIPS AND PEARLS

- Avoid ketamine in patients with ischemic cardiac disease because it causes stimulation of the sympathetic nervous system, leading to increases in blood pressure and heart rate, thereby inducing myocardial ischemia.
- There are no data that show improved outcomes with the routine use of fentanyl sympatholysis during emergency RSI of the cardiac or hypertensive patient. It introduces a third medication into the sequence, necessitating more time and a greater likelihood of a drug

administration error. It can be considered on a case-by-case basis depending on all available clinical information and provider judgment.

- Modify the dose of the sedative used; all have the potential to potentiate hypotension in patients suffering cardiogenic shock. Additionally, use a higher dose of neuromuscular blocking agent in patients with low-flow states to ensure effective and timely muscle relaxation.

EVIDENCE

Is there evidence for routine use of fentanyl during RSI of the patient with a cardiovascular emergency?

Fentanyl is commonly used in the OR to blunt the RSRL for patients suffering from a cardio or neurovascular crisis. In the ED, patients suffering from a cardiac emergency who need intubation typically present with hemodynamic extremes. In hypotensive patients or those at risk for hypotension, fentanyl needs to be used with caution. In a multicenter observational registry of ED intubations in Japan, the fentanyl group had a higher risk of PIH (adjusted OR, 1.87; 95% CI, 1.05-3.34; $P = .03$) compared with the nonfentanyl group.[1] In a sensitivity analysis, using propensity score matching, this association remained significant (OR, 3.17; 95% CI, 1.96-5.14; $P < .01$). Fentanyl is rarely used in the ED. In a recent analysis of approximately 15 800 medical patients from the National Emergency Airway Registry (NEAR), one-third were listed as "hypertensive" at the time of intubation, yet only 2% to 3% received fentanyl upstream from RSI medications.[2] To our knowledge, there are no outcome data that show improved survival or functional outcome when fentanyl is administered during emergency airway management.

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CHAPTER 40

Intubating the Highly Infectious Patient

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THE CLINICAL CHALLENGE

The Coronavirus Disease of 2019 (COVID-19) pandemic highlighted concern for the safety of health care workers when intubating a highly infectious patient. Anytime air passes over a liquid interface, as occurs during exhalation, aerosols are produced. Given the viral burden in the nasopharynx, there is risk that the aerosols produced contain virus that can then be transmitted to health care workers in the room. This is especially true given the focus on high flows, or positive pressure ventilation, used for preoxygenation in patients with hypoxemic respiratory failure, amplifying the concern of potentiating infectious aerosolized particles. Theoretical and experimental data suggest that there is likely a spectrum of respiratory secretion propagation and that the smaller the particle, the longer it may remain airborne and present a threat via inhaled viral transmission.[1] Thus, although no procedure can be deemed incapable of permitting infectious transmission, some procedures have been defined by the World Health Organization (WHO) as aerosol-generating procedures if there has been evidence to suggest they pose particularly high risk of disease transmission via aerosol generation.[2] Endotracheal intubation is included in this list as of May 2021.

In 2003, a coronavirus epidemic from “Severe Acute Respiratory Syndrome Coronavirus” (SARS-CoV or SARS-CoV-1) killed approximately 774 people, and it was noted that physicians and nurses performing intubation were at increased risk for infection relative to

providers present for other forms of ventilatory support.[3] Several follow-up studies also suggested that intubation was a high-risk procedure for infection transmission, but the risk was reduced by using personal protective equipment (PPE) such as N95 respirators and eye protection.[4,5] Notably, the overall number of infected health care workers was relatively low (26 infected of 624 total studies, 4%), and these studies did not control for factors that would theoretically reduce aerosol production, such as use of rapid sequence intubation (RSI).[5]

The 2009 H1N1 Influenza Pandemic reopened these questions of safety with aerosol-generating procedures. RNA was captured from small respiratory droplets to quantify the risk of viral transmission. Despite few patients, data supported the ongoing concern over aerosol-generating procedures, suggesting that they present a higher risk of RNA propagation than baseline room air samples.[6] However, a dichotomous distinction of "aerosol-generating procedure" versus "not" is artificially strict, and practice variation with aerosol-generating procedures (eg, RSI vs. spontaneous breathing during intubation) or patient-specific factors may significantly affect the risk of any procedure for a given patient.[7] Regardless of the definition used, for the safety of all health care workers in proximity to airway management, two primary themes are agreed to be central to minimizing risk of infectious transmission: (a) limit the exposure and (b) limit the aerosolization of viral particles (**Table 40.1**).

TABLE 40.1 Risk Mitigation Strategies for Intubating the Highly Infectious Patient

Limit the Exposure	Limit Aerosolization
Personal protective equipment (N95 respirator or PAPR, gloves, impermeable gown, eye protection)	Negative pressure rooms
Limit number of people in the room	RSI and higher dose NMBA
Frequent handwashing	Use EGD only as rescue device.
RSI prior to mouth opening procedures	
Skilled operator performing intubation	
Video laryngoscopy	
Standardized procedures/simulation to reduce	

communication errors	

NMBA, neuromuscular blocking agent; PAPR, powered air purifying respirator; RSI, rapid sequence intubation; EGD, extraglottic device

LIMITING EXPOSURE

The first step in limiting exposure is to work toward ensuring a smooth, well-planned strategy to limit laryngoscopy time and achieve first pass success. The use of appropriate PPE is a mainstay of limiting exposure and should be considered routine to limit risk of infection.[4] Experiences with early health care setting transmission of COVID-19 in China led to recommendations for increased protective gear during intubations, including N95 respirators or Powered Air Purifying Respirators (PAPR), eye protection, and a barrier gown.[8] Ideally, PAPRs should be used when available because they afford the greatest respiratory protection. If not available, N95 respirators and eye protection should be the minimum. It is very possible that even without aerosolized particles, body fluids may land on surfaces and permit transmission, such as with ebola virus disease.[9] Frequent handwashing, appropriate donning and doffing technique, and cleaning of all equipment with appropriate disinfecting solutions is crucial.[9,10] When performing RSI, any mouth-opening maneuvers should be reserved until the patient is fully paralyzed to avoid the possibility of biting in the case of blood-borne pathogens. Use a higher dosing range for neuromuscular blocking agents (at least 1.5 mg/kg IV of succinylcholine or rocuronium) to ensure rapid and complete paralysis. We recommend video laryngoscopy not only for improved first pass success but also for limiting exposure to bodily fluids by maintaining further distance between the operator and the patient.[11]

Several designs for barrier protection have been proposed to further limit exposure to infectious particles.[12,13] However, testing of these devices is critical prior to implementation to ensure efficacy because some have even been shown to potentially increase delivery of aerosol particles.[14] We do not recommend using barrier devices because they are unproven and potentially counterproductive and will limit mobility in the event of an aborted attempt caused by intubation difficulty.

There are significant challenges introduced by cumbersome PPE, air filtration systems, any barrier system used, and possible limitation of available tools in an isolation setting. Most notably, communication between members of the intubation team is greatly degraded, especially with the use of PAPRs/controlled air purifying respirators (CAPRs), where the fan creates noise. N95 respirators dampen the voice and cover the face, making it harder to hear what the person is saying or see facial expressions and nonverbal communication. Isolation rooms often render necessary equipment when faced with difficulty out of reach, because doffing and redonning or a team member outside are required. Thus, not only is a skilled operator the ideal provider to perform the intubation, but routine simulation in full PPE and isolation should also be performed to improve team performance.

LIMITING AEROSOL PRODUCTION

Limiting aerosolization can be broken down into environmental and procedural strategies. With regard to environmental strategies, an enclosed, negative pressure room has been suggested to decrease concentration of aerosolized particles and prevent transmission to surrounding areas.[15,16] Regarding procedural management strategies, quantitative studies suggest that a forceful cough generates more aerosol particles than does RSI.[17] Additionally, bag-mask ventilation with appropriate facial seal also does not appear to be particularly aerosol generating.[17] Other quantitative studies agree that a forceful cough results in more particle generation than intubation but found higher rates of particle generation.[18] The latter study did not control for the induction method, which may account for disparate findings.[18] Taken together, it appears that RSI along with steps taken to ensure a high chance of first pass success and limiting time in an enclosed space with the infectious patient are prudent procedural strategies.

NONINVASIVE OXYGENATION STRATEGIES AND RISK

Concerns have been raised regarding aerosol generation during noninvasive preoxygenation using high-flow oxygen delivery or positive pressure masks. Studies have reported mixed outcomes. In healthy volunteers, high-

flow nasal cannula (HFNC) has been demonstrated to potentially increase aerosolized particle generation.[19] In this same study, continuous positive airway pressure (CPAP) demonstrated reduced aerosolized particles.[19] However, other studies, also using healthy volunteers, have demonstrated that exertional breathing, which may be reduced by higher oxygen flow rates, was a more significant generator of aerosolized particles than either noninvasive modality.[20,21] Use of a surgical face mask over oxygen delivery methods does not appear to change the particle generation and is not recommended.[22] Based on remaining uncertainty, more studies are needed; however, there is not good evidence that advanced preoxygenation modalities with flush flow oxygen, high-flow nasal oxygen, or noninvasive positive pressure ventilation increase the risk to bedside providers involved in an intubation. The benefit to safety from these advanced preoxygenation methods in the setting of a severe pneumonia with hypoxemic respiratory failure warrants continued use of these noninvasive modalities with appropriate protective precautions.[23] Studies of extraglottic devices (EGDs) and aerosol generation are limited, and use of these devices should thus be reserved for rescue maneuvers only.[24] Placement of the device likely does not pose extremely high risk in situations where the patient is well relaxed and has no forceful coughing. However, there is potential for aerosol generation during controlled ventilation, as well as during removal of the device.[25]

TIPS AND PEARLS

- Intubation poses a high potential risk for infectious transmission.
- PPE is crucial to infection prevention and should include gloves, impermeable gown, face shield with eye protection, N95 respirators, and rigorous handwashing.
- Use preoxygenation methods as in noninfectious patients in the setting of adequate PPE.
- Barrier devices such as covered boxes or plastic drapes must be evaluated individually because safety and efficacy vary widely. We do not recommend routine use of these devices.

- Negative pressure rooms are suggested and likely reduce concentration of aerosolized particles containing viral RNA.
- RSI and all efforts to achieve first pass success may reduce transmission during intubation.
- Supraglottic airway devices (SADs) should be used as rescue devices only and replaced with a cuffed endotracheal tube as soon as safely possible.

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CHAPTER 41

The Massively Soiled Airway

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THE CLINICAL CHALLENGE

Airway management in emergency medicine, critical care, and prehospital medicine is often complicated by airway contamination in the form of blood or regurgitated material, especially in cases of out-of-hospital-cardiac arrest (OHCA).[1] Blood in the airway was cited as one of the leading causes of first-attempt intubation failure in the intensive care unit (ICU) setting, whereas multiple intubation attempts have been clearly linked to major complications.[2] Aspiration is also noted to be the primary cause of death in operating room and ICU tracheal intubations.[3,4]

A massively soiled airway (MSA) is the occurrence of upper airway obstruction and soilage owing to large amounts of regurgitated or expectorated liquids and solids that impairs oxygenation and ventilation and complicates basic and advanced airway management. Bag mask ventilation will inevitably worsen pulmonary aspiration. An extraglottic airway may be able to limit further aspiration and temporize oxygenation and ventilation but will not function optimally with an MSA and will undoubtedly need to be replaced with a cuffed endotracheal tube. Attempts to successfully intubate are often confounded by impaired visualization of laryngeal landmarks. The patient groups at risk for MSA include patients with gastrointestinal (GI) bleeding, near-term and full-term pregnancy, morbid obesity, GI obstruction, victims of major trauma, and anyone that has undergone extensive rescue mask ventilation with subsequent gastric insufflation.

APPROACH TO THE AIRWAY

Strategies to Prevent Regurgitation During Airway Management

Perhaps the most important strategies adopted to prevent regurgitation during airway management is the use of rapid sequence intubation (RSI) and positioning the patient in a head-up and foot-downward position. The use of cricoid pressure has now generally been debunked and the use of preinduction gastric drainage carries its own risk-to-benefit calculation.[5,6] If the patient has any limitations in the ability to protect their airway, the very placement of the gastric tube could lead to vomiting and aspiration. Furthermore, placing any foreign material through the lower esophageal sphincter carries a risk of promoting regurgitation. For these reasons, preintubation gastric drainage is generally limited to patients with upper GI bleeding and normal mental status. Pro-kinetic GI medications are sometimes utilized in the elective surgical population to offset the slow gastric emptying times secondary to gastroparesis but are unlikely to be helpful in emergent scenarios. Overall, none of these strategies are likely to be helpful if the oropharynx is already contaminated with blood, emesis, and/or secretions.

Strategies to Manage Regurgitation

The traditional approach to the MSA is to reposition the patient in a head-down or lateral position in order to use gravity to permit postural drainage of the pharynx, the nasopharynx as a reservoir for regurgitated material, and a rigid suction catheter (RSC) to further remove the airway contaminants.[7] For patients that require assisted ventilation prior to intubation—or when intubation is not an option—placement of an extraglottic device (EGD) that allows for a large-bore suction catheter is usually superior to mask ventilation; a retroglottic EGD such as the King Laryngeal Tube that blocks the esophagus might be particularly helpful. At the time of intubation, some experts have considered intentional placement of an endotracheal tube in the esophagus to redirect abdominal contents and allow for them to be suctioned.[8]

The newest approach to the MSA is the SALAD technique, an acronym for Suction-Assisted Laryngoscopy and Airway Decontamination.[9] The SALAD technique allows for the management of the MSA through the proactive use of an RSC to decontaminate the airway from mouth to larynx in a stepwise fashion. Ideally, an RSC with a substantially larger bore than a Yankauer device would be used. This RSC is inserted into the airway *prior to the insertion of the laryngoscope*, such that the laryngoscope is minimally exposed to airway contaminants. This is particularly important with video laryngoscopy, although both video laryngoscopy (VL) and direct laryngoscopy (DL) have been shown to be equally efficacious in soiled airways.[10]

As the suction catheter is advanced through the oropharynx, around the base of the tongue and into the hypopharynx, it removes airway contaminants in advance of the laryngoscope, preventing the airway contaminants from obscuring the illumination or visualization components. This is particularly important with video laryngoscopy. Following insertion of the laryngoscope, the RSC is maneuvered to the left of the laryngoscope blade to maintain hypopharyngeal decontamination and provide the necessary space for endotracheal tube insertion/delivery from the right side of the laryngoscope blade.

Aside from the benefits of preemptive suctioning of the airway, when the RSC is utilized as a physical distraction tool in advance of the laryngoscope, it will facilitate the laryngoscopy procedure with reduced need for tissue manipulation and adjustments to control the tongue with respect to its position on the laryngoscope blade. These maneuvers are all but identical to the maneuvers that are performed with the laryngoscope itself. In effect, you are placing a curved blade laryngoscope-shaped RSC to facilitate the insertion of an actual laryngoscope with the SALAD technique. The SALAD technique can also be utilized to assist the insertion of supraglottic airways and oral pharyngeal airways.

Steps of the SALAD Technique

Step 1: Suction-Assisted Laryngoscopy

The intubator begins the SALAD procedure with the RSC held in the right hand in an overhand fashion so that the curve of the RSC mirrors the shape

of both the upper airway and the shape of the curved laryngoscope (tip of RSC pointed downward and away from the endoscopist). Insert the RSC midline, sweeping laterally to decontaminate the oropharynx toward the base of the tongue and then hypopharynx. The RSC is gripped tightly like a laryngoscope and is used to displace the tongue and lower mandible inferiorly to maximize space for laryngoscope insertion. Manipulate the RSC in a manner similar to a curved blade DL to *compress the tongue into the floor of the mouth* and *lift the base of the tongue off the posterior pharyngeal wall* to create space for laryngoscope insertion (see **Fig. 41.1**).

Figure 41.1: Suction-assisted laryngoscopy.

Step 2: Achieving Laryngeal Visualization While Avoiding Soiling of the Optics

While continuing to use the RSC to displace the tongue anteriorly and provide suction in advance of the laryngoscope, the intubator advances the tip of the laryngoscope into the hypopharynx. The intubator should maintain the optics of the laryngoscope at the *highest vertical position*

possible relative to the patient's base of tongue and posterior pharyngeal wall to avoid soiling the optics by allowing it to touch the posterior pharyngeal wall where airway contaminants accumulate owing to gravity (see **Fig. 41.2**).

Figure 41.2: Laryngeal visualization.

Step 3: The SALAD Park

Maneuver the RSC from the *right* side of the laryngoscope to the *left* side with the tip in the upper esophagus, where it remains during intubation. This technique has been referred to as the "SALAD Park." Placement in the esophagus also minimizes the unintentional suctioning of supplemental oxygen from the upper airway. Should the clinician manage an airway in which the source of airway contamination is from the *oropharynx or nasopharynx*, the tip of the suction catheter is *withdrawn* from the esophageal inlet to allow the suction catheter to evacuate the airway contaminants flooding into the airway *from above the larynx* (see **Fig. 41.3**).

Figure 41.3: “SALAD Park” technique.

Step 4: The SALAD Poke

Endotracheal tube delivery can be simplified by manually dilating the space through which the endotracheal tube passes by inserting the index finger of the right hand alongside the right side of the laryngoscope blade in order to ensure that adequate oropharyngeal space exists (with adequate tongue control) to pass the tracheal tube into the larynx. This technique has been referred to as the “SALAD Poke” and is akin to utilizing a dilator to widen the path for the insertion of a central venous catheter. The SALAD Poke overcomes the difficulty with tracheal tube insertion when the endoscopist has not created this space proactively during blade insertion.

Step 5: Decontamination of the Tracheal Tube Prior to Ventilation

Endotracheal tube suctioning prior to the delivery of the first ventilation through the endotracheal tube. This step is intended to allow the caregiver the optimal chance to reduce aspiration and thoroughly decontaminate the airway during patient care.

SUMMARY

The MSA presents a major challenge to both basic and advanced airway maneuvers. Positioning, suctioning, and an extraglottic device may be helpful initially, but these patients require intubation as soon as possible, and this is best facilitated with the SALAD technique utilizing a large-bore suction catheter in a stepwise fashion.

TIPS AND PEARLS

- Preintubation gastric drainage is not recommended because the placement of the tube itself increases the risk of regurgitation.
- Position the patient with an MSA in a head-down or lateral position to utilize gravity to permit postural drainage of the pharynx.
- For patients that require assisted ventilation prior to intubation—or when intubation is not an option—placement of an EGD that facilitates a large-bore suction catheter is usually superior to mask ventilation.
- The SALAD technique utilizing a large-bore RSC is recommended when intubating a patient with an MSA.
- The RSC is more than a suction device. When gripped tightly like a laryngoscope, it is used to displace the tongue and lower mandible inferiorly to maximize space for laryngoscope blade insertion and to help “stay high and dry.”
- Maneuver the RSC from the *right* side of the laryngoscope to the *left* side with the tip in the upper esophagus, where it remains “parked” during intubation.

EVIDENCE

Is there evidence to support the SALAD technique?

There is a growing body of evidence from simulated contaminated airways that demonstrates the clinical utility of the technique.[11-14] There are two published case reports demonstrating the clinical effectiveness of the SALAD technique—a case involving the induction and intubation of a patient with gastric outlet obstruction involving the regurgitation of 3 L of gastric fluid and a case involving the management of a patient in severe pulmonary edema whose condition created a deluge of fluid pouring forth from her respiratory tree, obscuring the larynx.[15,16] There are no large case series or randomized trials yet evaluating the SALAD technique.

How do you recommend training airway practitioners to manage the MSA?

The SALAD technique requires dedicated experiential training on an airway mannequin task-trainer modified to express copious amounts of simulated airway contaminant. Construction of SALAD simulation mannequins has been described in multiple online medical blogs as well as the peer-reviewed literature.[17,18] A commercially available mannequin constructed to allow the SALAD simulation is available from Nasco as the Life/form S.A.L.A.D. Simulator.

Is one rigid suction catheter better than another?

For the massively contaminated airway, a typical Yankauer catheter has very limited utility. Large-bore RSCs are commercially available from at least two manufacturers, CONMED and SSCOR, Inc., and facilitate the removal of large amounts of liquid and partial solid airway contaminants.

Is there an advantage of video versus direct laryngoscopy for the MSA?

Within the SALAD simulation studies that utilize standard geometry versus hyper-curved geometry video laryngoscopes, there are no firm conclusions of the superiority of either type of device. In a retrospective analysis of NEAR III GI bleed intubation data, both DL and VL had similar rates of success and glottic views.[19] Another respective cohort study examining intubation and trauma in the ED suggests that the VL (72%) may hold an advantage over DL (63%) in achieving first pass success.[20] An observational study of ED intubations found the first pass success rate was higher with the GlideScope (81%) than the direct laryngoscope (66%) in

590 patients with airways soiled with blood or vomitus. 10 Severe lens contamination rendering the GlideScope unusable only occurred in 1.3% of patients with a soiled airway. Video laryngoscopes that have standard geometry (ie, Macintosh shape) have the advantage of continuing to provide clinical utility if their imaging systems are obscured by airway contaminants. It is important to practice laryngoscopy in such a manner—stay high and dry—that the video module of the endoscope is positioned as *close to the base of the tongue, superior to the posterior pharyngeal wall* to limit the contamination of the light source.

Is there a role for point-of-care abdominal ultrasound to estimate gastric volume?

Imaging of gastric volume is of limited utility in emergency scenarios that require swift rescue and control of a patient's oxygenation and ventilation. This technique has a growing body of evidence as a clinically relevant tool for preprocedure assessment prior to anesthetic care in which adequate time and opportunity exist to optimize a patient prior to induction and airway management.[21]

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CHAPTER 42

The Geriatric Patient

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THE CLINICAL CHALLENGE

Comorbid illnesses are common in the older population, and for any given illness or injury, older adults have a worse outcome than younger adults. Aging causes progressive deterioration in physiologic reserve often exacerbated by preexisting chronic conditions, so older patients are at increased risk of peri-intubation adverse events. Cardiovascular morbidity, pulmonary pathology, frailty syndromes, and chronic underlying conditions are particularly relevant in avoiding the pitfalls of airway management in geriatric patients. Older patients requiring emergency airway management are likely to have significant comorbidities. Older adults are also increasingly obese and, paradoxically, most likely to be malnourished. They may require airway management for multiple reasons; however, their expected clinical course is often the most important factor in deciding to intubate in the emergency department (ED). Even without an immediate threat to oxygenation, ventilation, or airway protection, the older patient often has a more prolonged and complex clinical course, requiring airway support as part of their therapy. Conversely, the use of noninvasive ventilation techniques may provide an important bridge during information gathering, medical decision-making, and family discussions.

Decreased Cardiorespiratory Reserve

Age-related changes in the lungs impair gas exchange, reducing oxygen tension at baseline. The normal Pao_2 falls by 4 mm Hg per decade after the age of 20. Total lung capacity does not change significantly, but functional

residual capacity (FRC) and closing volume (CV) increase with age. CV increases more than FRC, leading to atelectasis, especially in the supine position. Reduced sensitivity of central respiratory drive, weakened respiratory muscles, and altered chest wall mechanics impair the ability of the older adult to respond to hypoxia and hypercarbia. Consequently, oxygen saturation may fall rapidly in the face of a respiratory threat. Older patients are also at risk of pulmonary aspiration because of blunted airway reflexes, swallowing disorders, drug effects, and delayed gastric emptying. Older patients with chronic obstructive pulmonary disease (COPD) or obstructive sleep apnea may live with partially compensated respiratory insufficiency, be on home oxygen, or require respiratory support at baseline through nasal continuous positive airway pressure (CPAP) machines.

The aging heart often has reduced contractility, reduced coronary blood flow, and chronic dysrhythmias, further impairing its ability to increase cardiac output. β-Blockers and calcium channel blockers may limit responses to physiologic stresses by preventing compensatory elevations in heart rate. A relatively fixed cardiac output impairs the physiologic response to the vasodilatory effects of intubation drugs. Finally, the presence of cardiovascular or cerebrovascular disease reduces the patient's tolerance of hypoxemia or hypotension.

Older patients are more prone to postintubation hypotension, which may be severe and persistent after the intubation is complete. In addition to age, patients presenting with an elevated shock index (heart rate divided by systolic blood pressure), respiratory failure, or history of end-stage renal failure and chronic renal insufficiency are at increased risk for peri-intubation complications. Overall, postintubation cardiac arrest occurs in about 1% of patients immediately following rapid sequence intubation (RSI), with pulseless electrical activity (PEA) being the most common rhythm. Older patients with postintubation hypotension are at highest risk for progressing to cardiac arrest. In hemodynamically vulnerable patients, volume resuscitation and blood pressure support in advance of intubation, if time allows, is advisable.

Older patients are more likely to present to the ED *in* cardiac arrest. Recent focus on the optimal airway management strategy in primary cardiac arrest suggests that definitive airway placement is not beneficial during the immediate cardiac arrest period. Clinical teams should focus on

quality chest compressions, oxygenation, and limiting overventilation, which can impede venous return. This is discussed in more detail in the Evidence section. However, if intubation is performed, a patient in cardiac arrest usually has a technically straightforward intubation because they lack skeletal muscle tone and protective reflexes. Management for patients in cardiac arrest should follow accepted advanced cardiac life support (ACLS) algorithms and is focused on less invasive airway maneuvers during arrest (ie, placement of an extraglottic device [EGD] or manual bagging), followed by definitive airway management if the arrest is prolonged or return of spontaneous circulation is achieved.

Increased Incidence of Difficult Airways

Advanced age is a marker for difficult bag-mask ventilation (BMV) (see Chapter 2). Older patients also have an increased incidence of difficult direct laryngoscopy as a result of impaired neck mobility and mouth opening. A fixed flexion deformity of the neck may be unrecognized until the pillow is removed prior to intubation; intubation with conventional laryngoscopy is challenging under these conditions (see **Fig. 42.1**). Additionally, patients with rheumatoid arthritis and other inflammatory arthritic conditions may have unstable upper cervical spines. The mucosa of older adults is more friable, often desiccated, and less elastic, making them more vulnerable to damage. Similarly, changes associated with aging and the cumulative effects of disease may cause difficulty with the insertion of EGDs and provision of a surgical airway. For all of these reasons, maximizing the opportunity for first-attempt success through proper positioning, robust preoxygenation, and the liberal use of intubating introducers and video laryngoscopy is recommended.

Figure 42.1: Fixed flexion deformity in an elderly patient. This leads to difficult laryngoscopy and poor glottic visualization."

Ethical Considerations

In airway management, as in all other aspects of resuscitation, the patient's preferences regarding therapeutic interventions must be respected. Advanced age is not a contraindication to advanced airway intervention. Poor outcomes relate more to functional limitation and comorbidities rather than to chronologic age. In cases where life-sustaining interventions are either inappropriate or not desired, noninvasive positive pressure ventilation

can provide respiratory assistance and comfort. CPAP or bilevel positive airway pressure can also act as a temporizing measure when data are lacking and information about advanced directives is gathered prior to intubation. This is addressed in the Evidence section.

APPROACH TO THE AIRWAY

As older patients tolerate hypoxia poorly, intubation should be considered early in their management. A careful preintubation assessment will identify difficult airway predictors, such as poor mouth opening, stiff lungs, and reduced cervical spine range of motion. Most often, the operator will be confident with the predicted success of video laryngoscopy and oxygenation using a bag and mask or EGD, so RSI is typically the technique of choice, as with other age groups. Regardless of the results of a bedside assessment for difficulty, in older patients, one should be prepared for an unexpected difficult airway. This requires planning, communication, and preparation of rescue airway devices.

Preoxygenation is particularly important because older patients may desaturate quickly because of age-associated changes in the heart and lungs and preexisting disease. For the same reasons, preoxygenation may not be as effective as in a younger, healthier patient. Use of face mask oxygen at a flush flow rate of at least 40 to 50 L/min, and apneic oxygenation should be considered early if preoxygenation through more traditional means is not adequate. BMV may be required to maintain oxygen saturation >93% after the induction agent and neuromuscular blocking agent (NMBA) are given, particularly if more than one laryngoscopic attempt is required. During BMV, the mask seal may be problematic because of facial wasting and edentulousness, and a two-handed two-person technique, with a nasal or oral airway, is the best technique. Well-fitting dentures should be left in place during BMV and removed for intubation, or EGD placement. If the dentures are displaced, poorly fitting, or already acting as a foreign body, they should be removed. Loss of elastic tissues promotes collapse and partial obstruction of the upper airway. Obesity adds to the redundant tissue in the upper airway, which may precipitate a functional obstruction with loss of tone. Older patients may have oropharyngeal obstruction because of hematoma or cancer of the head and neck. Reduced lung compliance and

chest wall stiffness may make oxygenation using a bag and mask or EGD difficult, and this may be worsened by coexisting COPD or heart failure.

When a preintubation assessment identifies a difficult airway, the operator should choose a video laryngoscope and ensure optimal patient positioning to create the greatest likelihood of success. Have an intubation introducer, such as a gum elastic bougie, readily available. Alternative airway approaches, including awake flexible endoscopy, may be chosen over RSI, as guided by the difficult airway algorithm (see Chapter 5). Cricothyrotomy is often required in a "can't intubate, can't oxygenate" situation, but this procedure may be difficult in the older patient because they are more likely to have distortion of the tissues as a result of cancer or radiotherapy or limited access, as in the case of a fixed flexion deformity involving the cervical spine.

Drug Dosage and Administration

Physiologic Optimization

In general, older patients have less physiologic reserve than younger adults and are more susceptible to the hypotensive effects of sedative agents. With this in mind, physiologic optimization to maximize the patient's cardiovascular physiology and mitigate the profound hypotension or circulatory collapse that can happen even with modest doses of induction drugs is critical.

Delayed sequence intubation, discussed in Chapter 20, may be particularly well suited to the geriatric population who are more likely to be acutely confused and agitated prior to intubation and are at greater risk for hypoxemia than younger adults. The use of a dissociative dose of ketamine (1 mg/kg IV) to reduce agitation and oxygen consumption and increase compliance with oxygen delivery may result in less frequent and less severe hypoxemic events. It is preferred in older hypotensive patients, or those who arrive in shock, to administer a pressor agent to mitigate peri-intubation circulatory collapse. This includes consideration of push-dose pressors, usually phenylephrine or epinephrine, in small doses to reverse hemodynamic instability. However, the evidence for benefits from push-dose pressors is not robust, and administration is associated with a substantial risk of human error. The preferred approach involves titrating a

norepinephrine infusion to support blood pressure before RSI medications are administered. This allows titration by other members of the team while airway managers focus on the intubation itself. In addition, patients requiring norepinephrine upstream from the intubation will typically require it to support hemodynamics afterward, and, therefore, having it in place at the time of the procedure makes logistical sense.

Paralysis With Induction

Etomidate remains the preferred induction agent in older patients because of its superior hemodynamic stability, although in profoundly compromised patients a full induction load may still precipitate hypotension or loss of vascular tone. The standard induction dose should be reduced by half in older patients, and a two-thirds reduction is advisable if significant hemodynamic compromise exists. Propofol may cause significant hypotension in critically ill patients and is not recommended as the primary induction agent for older patients requiring RSI.

Ketamine causes less cardiovascular instability than propofol and is useful in younger patients with hypotension and adequate adrenal reserve; however, its sympathomimetic properties may be problematic in patients with ischemic heart disease, cerebrovascular disease, or Parkinson disease. Additionally, ketamine exerts its hemodynamic support through indirect catecholamine release. In older patients, adrenal reserve may be limited and absent, resulting in paradoxical hypotension and loss of vascular tone. Therefore, in compromised older patients, etomidate is the primary induction agent (see Chapter 21).

Older adults are more likely to have an acquired contraindication to succinylcholine, predominantly a neurologic injury or a degenerative neuromuscular disorder. If the decision is made to use succinylcholine in older patients, seek contraindications from the patient, prehospital providers, family members, or medical records. A quick physical examination may reveal neurologic deficits that, if more than 3 days old, place the patient at risk for receptor-mediated hyperkalemia. Chronic renal disease, including renal failure, is not a contraindication to succinylcholine use. Many providers now use rocuronium as their primary NMBA, especially in older patients. The dose is the same as in younger adults, using actual body weight dosing.

POSTINTUBATION MANAGEMENT

The principles of postintubation management, set out in Chapters 10 and 20, are appropriate to the aging adult. Anticipate greater sensitivity to both the sedative and hemodynamic effects of sedatives (eg, propofol) and analgesics (eg, morphine, fentanyl) and titrate accordingly. NMBAs are rarely required. If used, the NMBA should also be given in reduced doses and with increased intervals between doses. Reduced lung compliance may increase ventilation pressures in older patients. In COPD, it is advisable to limit peak pressure and allow a prolonged expiratory phase, although severe respiratory acidosis should be avoided in ischemic heart disease. Positive pressure ventilation, particularly with high levels of positive end-expiratory pressure, can cause hypotension, particularly if hypovolemia is present, and may exacerbate the hypotensive effects of sedative drugs. Pressure-controlled ventilation is the preferred mode.

TIPS AND PEARLS

- Older patients have an increased incidence of both anatomic and physiologic difficulties. These challenges are identified and managed in generally the same fashion as for the younger patient. RSI is usually the procedure of choice.
- Older patients desaturate quickly, emphasizing the importance of preoxygenation. Passive oxygenation during apnea (oxygen at 15 L/min by nasal cannula) may delay desaturation. If hypoxia develops quickly, BMV or rescue with EGD may be required after induction or between intubation attempts. Delayed sequence intubation may be useful in older adults because of agitation and delirium.
- Age-related cardiovascular changes, preexisting disease, and drug interactions enhance the hypotensive response to induction, and reduced doses of sedatives and hypnotics should be used. Reduced cardiac output prolongs the arm-brain circulation time, and a delayed onset of action should be anticipated for all intravenous drugs.

EVIDENCE

What is the cardiovascular risk of intubation in older patients?

Older patients are at risk for adverse hemodynamic consequences following intubation, both from the cardiovascular effects of induction drugs and from the decreased venous return that accompanies positive pressure ventilation. Older patients are more likely to be malnourished and dehydrated, resulting in lower intravascular volumes.[1] Peri-intubation hypotension is common, occurring in as many as 25% of all patients.[2] One single-center ED intubation registry reported an association between age and postintubation hypotension, with age >70 years being an independent predictor.[3] Patients experiencing peri-intubation hypotension were nearly 15 times more likely to die during their hospitalization.[4] Hypotension during intubation was not confirmed as the cause of increased mortality but identified a high-risk group, susceptible to hemodynamic disturbances, that put them at risk for dying during hospitalization. Recent data from more than 15 000 encounters in the National Emergency Airway Registry (NEAR) project showed an overall rate of peri-intubation cardiac arrest of approximately 1%. The adjusted odds of peri-intubation cardiac arrest was highest in those who arrived in shock (aOR > 6).[5] When time allows, vulnerable patients requiring intubation should have volume resuscitation prior to intubation, reduced dose induction agent use, and support with vasopressors to mitigate hemodynamic compromise. Unfortunately, patients may still experience peri-intubation hypotension despite adequate fluid resuscitation.[6]

Is older age a predictor of difficult intubation or complications of intubation?

Older age is an independent predictor of difficult intubations and adverse peri-intubation events.[7] Older patients have a higher overall rate of difficult laryngoscopy.[8,9] Patients older than 80 years and those with predicted difficult airways such as Mallampati class III and IV are more likely to sustain an airway injury during anesthesia.[10] Deciding to proceed with intubation is appropriately based on the original indications for intubation (failure to ventilate, failure to protect airway, and the anticipated clinical course). Survival following emergency airway management in older patients is likely to be a product of the acute illness and background comorbidities rather than directly from the act of intubation.[11]

Which muscle relaxant should be used for RSI in the older patient?

Older patients are more likely to have an acquired contraindication to succinylcholine, most commonly a recent stroke; however, any upper or lower motor neuron defect at least 72 hours old puts the patient at risk for postsynaptic receptor upregulation and hyperkalemia.[12] Disuse atrophy is also a risk factor in the older age group. Theoretically, the risk of massive release of intracellular potassium is present only between 3 days and about 6 months after an acute stroke, when acetylcholine receptors proliferate at the neuromuscular end plate. In reality, many ED patients requiring emergent intubation are unable to provide a complete history, and many emergency physicians will opt to use rocuronium instead of succinylcholine for RSI in older patients.[13]

Are push-dose pressors safe and effective in older patients?

Push-dose pressors or bolus-dose vasopressors consist of small doses of vasopressor agents such as phenylephrine or epinephrine to help maintain or obtain hemodynamic stability. There is little evidence focused on older patients, although published studies of push-dose pressors tend to be reporting on older adults. Evidence for the effectiveness of push-dose pressors is not substantial, and the risks of an adverse reaction or medication error are high.[14,15]

What are the outcomes for older patients who require ED intubation?

Recently published literature confirms what ED physicians have long suspected: survival to discharge and return to home following an ED intubation are substantially affected by a patient's age, with older patients being less likely to survive and return to home. For patients over 65 years of age, ED intubation is associated with a 35% in-hospital mortality. For patients over 90 years of age, this number rises to 50%, and only 14% will return home.[16] This information should prompt discussion of goals of care with patients and their families.[17] Patients with respiratory distress can have substantial relief with noninvasive methods of ventilation or consideration of a time-limited intubation trial.

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CHAPTER 43

The Morbidly Obese Patient

Megan Leigh Fix

THE CLINICAL CHALLENGE

The World Health Organization and the National Institutes of Health define a person to be overweight when he or she has a body mass index (BMI) between 25 and 29.9 kg/m^2 and a person to be obese when BMI >30 kg/m^2. This is called Class I Obesity. Class II obesity (formerly known as morbid obesity) is defined as a BMI between 35 and 39.9 kg/m^2. Class III Obesity (formerly known as severe obesity) is defined as a BMI ≥ 40 kg/m^2. The National Health and Nutrition Examination Survey for 2017 to 2018 estimates that 42.4% of the adults in the United States are obese. The 2017 Behavioral Risk Factor Surveillance System, a state-based cross-sectional random survey of the adult population of the United States, showed considerable differences in the prevalence of obesity across states. The United Kingdom's fourth National Audit Project (NAP4) reported that morbidly obese patients are at a 4-fold higher risk of major complications (death, brain damage, emergency surgical airway, unanticipated or prolonged ICU admission) when compared with nonobese patients following airway management.

APPROACH TO THE AIRWAY

As for all patients, managing the airway of obese patients requires a structured, methodical assessment to identify the specific predictors of difficult bag-mask ventilation (BMV), tracheal intubation, extraglottic device (EGD) placement, and cricothyrotomy. It is controversial whether obesity alone is a predictor of difficult laryngoscopy or whether obese patients tend to have a higher incidence of other markers of difficult intubation. Patient attributes differ, and some obese patients may have

multiple anatomic risk factors for airway difficulty in addition to obesity, whereas others may not. Nevertheless, morbidly obese patients develop both physiologic and anatomic changes that can make airway management particularly challenging because they have excess adipose tissue not only on the breast, neck, thoracic wall, and abdomen but also, internally, in the mouth and pharynx. When compared with lean patients, this excess tissue makes accessing the airway (intubation and tracheostomy) and maintaining patency of the upper airway more difficult.

Obese patients are also more likely to pose physiologic challenges during airway management. The degree of pathologic, physiologic, and anatomic changes correlates with the degree and extent of obesity and comorbidities common with obese patients. The physiologic and anatomic changes associated with morbid obesity are listed in **Box 43.1**. The main effects of obesity on airway management are (a) rapid arterial desaturation secondary to a decreased functional residual capacity (FRC) and increased oxygen consumption; (b) difficult airway management, specifically difficult BMV, resulting from increased risk of obstruction from excess pharyngeal adipose tissue and increased resistance resulting from the weight of the chest wall and the mass of abdominal contents limiting diaphragmatic excursion; and (c) difficult laryngoscopy, intubation, and cricothyrotomy.

BOX 43.1 Physiologic and Anatomic Changes Associated With Obesity

Physiologic changes associated with obesity according to system	Anatomic changes associated with obesity
Pulmonary:	
Increased intrathoracic pressure with a restrictive respiratory pattern: ↓FRC, ↓ERV, ↓TLC	Increased facial girth and tongue size. Smaller pharyngeal area.
Increased WOB, decreased MVC	Redundant pharyngeal tissue (risk of obstructive sleep apnea)
V/Q mismatch (predisposes to hypoxemia)	Increased neck circumference
Risk of pulmonary HTN	Increased chest girth
Obesity hypoventilation syndrome	Increased breast size
	Increased abdominal girth

Cardiac:	
Increased cardiac output	
Increased BV, SV	
HTN, LVH	
Increased metabolic rate: ↑VO_2, ↑CO_2 production	
Renal:	
Increased RBF and GFR	
Hepatic/gastrointestinal:	
Fatty infiltration of the liver	
Increased intra-abdominal pressure	
Risk for hiatal hernia, GERD	
Endocrine:	
Increased risk of diabetes	
Hyperlipidemia	
Hematologic:	
Increased risk of DVT	
Polycythemia (with chronic hypoxemia)	
Musculoskeletal:	
Degenerative joint disease	
Decubital changes	

BV, blood volume; DVT, deep venous thrombosis; ERV, expiratory reserve volume; GERD, gastroesophageal reflux; LVH, left ventricular hypertrophy; SV, stroke volume; Vo2, oxygen consumption.

Obesity affects nearly every aspect of normal physiology, most notably the respiratory and cardiovascular systems. Obese patients often have baseline hypoxemia with a widened alveolar-arterial oxygen gradient primarily because of ventilation-perfusion (V/Q) mismatching. Lung volumes develop a restrictive pattern with multiple disturbances, the most important of which is decreased FRC. These indices change exponentially with the degree of obesity. The decline in FRC has been ascribed to “mass

loading” of the abdomen and splinting of the diaphragm. Reductions in FRC limit the available potential space typically used to build an oxygen reservoir during the preoxygenation phase of rapid sequence intubation (RSI). FRC may be reduced to the extent that it falls within the range of closing capacity, thus leading to small airway closure and V/Q mismatch. The FRC declines further when the individual assumes the supine position, resulting in worsening of the V/Q mismatch, right-to-left shunt, and arterial hypoxemia. Although the vital capacity (VC), total lung capacity (TLC), and FRC may be maintained in mild obesity, they can be reduced by up to 50% in severely obese patients. The decreased FRC causes rapid oxyhemoglobin desaturation during the apneic phase of RSI, even in the setting of adequate preoxygenation (see Chapter 8).

The work of breathing (WOB) is increased 30% to 400% in morbidly obese patients because of decreased chest wall compliance, increased airway resistance, and an abnormal diaphragmatic position. These changes limit the maximum ventilatory capacity (MVC). The obese patient also has elevated oxygen consumption and carbon dioxide (CO_2) production because of the metabolic activity of the excess body mass. Risks of pulmonary hypertension (HTN) and obesity hypoventilation syndrome also increase with obesity. The increased abdominal pressure and subsequent risk of gastric acid aspiration can lead to aspiration pneumonitis.

Cardiovascular changes in obesity include increased extracellular volume, cardiac output, left ventricular end diastolic pressure, and left ventricular hypertrophy (LVH). The absolute total blood volume (BV) is increased, but it is relatively less on a volume/weight basis when compared with lean patients (50 mL/kg vs 75 mL/kg). Cardiac morbidity, including HTN, ischemic heart disease, and cardiomyopathy, correlates with progressive obesity.

Other changes include an increase in renal blood flow (RBF) and glomerular filtration rate (GFR), fatty infiltration of the liver, and a propensity for diabetes mellitus and obstructive sleep apnea (OSA) (Box 43.1).

Increased chest wall weight, facial girth, and redundant pharyngeal tissue all contribute to defining obesity as an independent risk factor for difficult BMV (see Chapter 2). Obese patients tend to have a smaller

pharyngeal space because of deposition of adipose tissue in the tongue, tonsillar pillars, and aryepiglottic folds. Patients with obesity have an increased risk of OSA, another independent risk factor for difficult BMV. Difficult BMV should be anticipated in the obese patient, often requiring a two-person technique with both oral and nasopharyngeal airways in place. In severe or superobese patients, BMV may simply be impossible because the mask seal pressure required to overcome the increased weight and resistance may be far in excess of that possible with a bag and mask. In addition, challenging BMV is associated with difficult intubation in 30% of the cases.

Intubation difficulty is also associated with increased neck circumference and high Mallampati scores. Cricothyrotomy is more difficult because of the increase in neck circumference, the thickness of the subcutaneous tissues, anatomic distortions, and adipose tissue obscuring landmarks, often requiring deeper and longer incisions. EGDs may not be able to overcome the high resistance of the weighted chest wall and restricted diaphragms. Second-generation EGDs, such as the LMA supreme, can provide higher leak pressures (25-30 cm H_2O) and may be preferable in obese patients.

TECHNIQUE

Morbidly obese patients vary with respect to airway difficulty, and a methodical LEMON assessment is essential to anticipate and plan appropriately for intubation (see Chapter 5). When the airway appears particularly difficult, the difficult airway algorithm advocates for careful preparation and an awake approach with topical anesthesia and, if necessary, light sedation.

Proper positioning is essential in obese patients in order to ensure adequate preoxygenation as well as the best attempt at laryngoscopy and tracheal intubation. Ideally, the patient should be placed in an upright or “ramped” position during preoxygenation. Laryngoscopy may need to be performed with the patient semierect if alveolar de-recruitment and rapid desaturation is likely when supine. If the patient is unable to sit upright, propping up on linens or on a commercially available wedge pillow, from the midpoint of the back to the shoulders and head for proper positioning,

as shown in **Figure 43.1**, may help. To confirm proper positioning, the patient should be viewed from the side, and an imaginary horizontal line should be able to be drawn from the external auditory meatus to the sternal notch. This position facilitates more effective preoxygenation and prolongs the duration of time before arterial desaturation with apnea.

A B

Figure 43.1: A: Patient is supine with the weight of the breast/chest obstructing access to the airway. B: Patient is propped on linens to establish better anatomic landmarks and remove the weight of the breasts/chest off the airway. Here, it is possible to draw an imaginary horizontal line from the external auditory meatus to the sternal notch.

Effective preoxygenation is of utmost importance in obese patients because they desaturate at a much faster rate than other patients. Although 3 minutes of tidal volume (TV) breathing or eight VC breaths with 100% FIO_2 (best achieved using flush rate oxygen and a non-rebreather mask) are recommended in the general population, these techniques may prove insufficient in the obese population. Noninvasive positive pressure ventilation (NIV) and positive end-expiratory pressure (PEEP) can be used if ambient pressure oxygenation is suboptimal and alveolar recruitment is deemed necessary. Preoxygenation is challenging in the supine position and, unless contraindicated, obese patients should be upright or in the reverse Trendelenburg position. Use apneic oxygen via nasal cannula at 15 L/min flow to extend the period of safe apnea.

When time and conditions permit, particularly in the morbidly obese patient, or the obese patient with additional markers of difficult laryngoscopy, an awake technique with either flexible endoscopy or video laryngoscopy is the preferred method. No matter which route is chosen,

proper airway equipment must be available and checked for proper functioning and, ideally, assistance is readily available in the event intubation proves to be exceedingly difficult. Video laryngoscopy is preferred because it has a greater likelihood of providing an excellent view of the glottis. When performing direct laryngoscopy (DL), a short-handled laryngoscope will be easier to insert because the chest prevents the longer handle from gaining blade access to the mouth. During ventilation by BMV or EGD, placing the patient in reverse Trendelenburg or a semiupright position reduces upward pressure against the diaphragm by the abdominal contents and may also mitigate some of the “weight effect” of chest wall tissues, such as the breasts. Both the standard and the intubating laryngeal mask airway have been shown to be effective in providing ventilation, with the latter also serving as a conduit for tracheal intubation. Video laryngoscopy has been shown to be successful in managing the airway of the obese patient and is the default device for emergency airway management when orotracheal intubation is planned. During DL, a bougie may be helpful when one encounters a suboptimal glottic view and should be readily available.

BMV often requires two providers using two-handed bilateral jaw thrust and mask seal, with oropharyngeal and nasopharyngeal airways in place. If manual bagging is anticipated to be challenging, an airway pressure relief valve can be used and set so that continuous positive airway pressure (5-15 cm H_2O) is delivered. This may help the stent open the pharynx and more distal airways and improve the effectiveness of BMV. It is important to try and pull the mandible up into the mask rather than push the mask down into the face. We recommend the “thenar grip” for BMV in obese patients (see Chapter 12). Relaxation of the upper airway muscles during RSI will often cause collapse of the adipose-laden, soft-walled pharynx between the uvula and the epiglottis, making BMV and tracheal intubation more difficult. This greatly reinforces the need to use oral and nasal airways, augmented by positioning the patient semiupright, as described earlier.

Cricothyrotomy may be extremely challenging in the severely obese patient because the chin may be directly contiguous with the chest wall, making identification of and access to anatomic landmarks difficult. Take care to ensure that landmarks are found. Bedside ultrasound can be used to

identify the cricothyroid membrane, and if time permits, the skin can be "dotted" or "marked" with a pen prior to starting the intubation attempt. If cricothyrotomy is performed, it may be necessary to have one or two assistants available to hold or retract neck, facial, and chest fat folds. As in all patients, cricothyrotomy is a tactile procedure. The open bougie-aided cricothyrotomy is the preferred technique, as with other patients (see Chapter 19). Finally, owing to increased neck diameter, many tracheostomy tubes will not be long enough for the morbidly obese patient. Use a 6-0 endotracheal tube (ETT), advanced through the cricothyrotomy incision, for definitive airway placement.

Drug Dosage and Administration

Obesity, along with any associated comorbidities, affects all aspects of the pharmacodynamic and pharmacokinetic properties of medications, including absorption, onset, volume of distribution (V_d), protein binding, metabolism, and clearance. In the obese patient, there is not only an increase in adipose tissue but also an increase in lean body mass of approximately 30% of the total excess weight. The ratio of fat to lean mass increases, however, causing a relative decrease in the percentage of lean mass and water in obese patients when compared with lean patients. In addition, there is an increase in blood volume and cardiac output. The V_d for a particular agent is affected by the combination of these obesity-associated factors, along with the specific lipophilicity of the drug. Protein binding is affected by an increased concentration of lipids, which limit the binding of some drugs, thus increasing the free plasma concentration. In contrast, increased a_1-glycoprotein may increase protein binding of other drugs, thus decreasing the free plasma concentration. For most agents that undergo hepatic metabolism, there is minimal change in effective half-life despite the high incidence of fatty infiltration of the liver. Agents handled by the kidney, however, have accelerated clearance because of increased GFR. These pharmacokinetic and pharmacodynamic changes can make the net effect of these agents somewhat unpredictable, and dosage adjustment may be required.

In general, the lipophilicity of the agent can indicate the dosage requirement. Most anesthetic agents are lipophilic, and thus an increase in

V_d and dose of the drug is expected, but this is not consistently demonstrated in pharmacologic studies because of factors such as end-organ clearance or protein binding. Less lipophilic agents such as neuromuscular blockers stay in the water compartment and have little or no change in V_d. This argues, in general, for ideal body weight (IBW) dosing. However, in the context of emergency RSI, optimal intubating conditions created by appropriate sedation and neuromuscular blockade are paramount. Succinylcholine is a total body weight (TBW) drug, despite its hydrophilic nature. This has been very well studied (see Chapter 22) and is related to enhanced pseudocholinesterase activity in morbidly obese patients. The same is true for rocuronium. IBW dosing has been shown to be *adequate* to manage obese patients in the controlled environment of the OR; however, in the ED, it could create a "worst case scenario" of an incompletely paralyzed, rapidly desaturating difficult emergency intubation. In this scenario, a low dose of rocuronium could result in ineffective or absent intrinsic ventilatory drive, yet inadequate relaxation and mouth opening to permit laryngoscopy. TBW dosing will prolong rocuronium's activity, but with a baseline duration of action of 45 minutes, there is little downside to this approach. In addition, the manufacturer's recommendation is TBW dosing. Therefore, for emergency RSI, we advocate for TBW dosing for all neuromuscular blockers to *avoid underdosing* and the resultant suboptimal intubating conditions. If induction agents are given in overdose, it can produce cardiovascular depression, and therefore dosing should aim to *avoid overdose*. We advocate for induction agents to be dosed based on lean body weight (LBW) in the morbidly obese patient. **Table 43.1** summarizes dosing adjustment recommendations for common RSI medications.

TABLE 43.1 Dosing Recommendations for Drugs Commonly Used in Airway Management

Drug	Dosing	Comments
Propofol	LBW	Lipophilic, systemic clearance, and V_d at steady state correlate well with TBW. High affinity for excess fat and other well-perfused organs. High hepatic extraction and conjugation relate to TBW. Cardiovascular depression limits dosage to LBW for use in induction. Maintenance dosing may be initiated at TBW but titrated to effect using sedation scales.

Etomidate Ketamine	LBW LBW	Increased V_d, dose may need to be decreased with liver disease Lipophilic, extensive hepatic first-pass metabolism. LBW for use in induction.
Succinylcholine	TBW	Hydrophilic, increased plasma cholinesterase activity increases in proportion to body weight.
Vecuronium	TBW	Hydrophilic, V_d increased and clearance decreased; however, optimal intubating conditions argue for TBW dosing.
Rocuronium	TBW	Hydrophilic, V_d increased and clearance decreased; however, optimal intubating conditions argue for TBW dosing.

LBW, lean body weight; TBW, total body weight.

Drug dosing for obese patients can be difficult to remember, given that some drugs are dosed on LBW and some with TBW. IBW, required to calculate LBW, must be estimated or looked up in a table or nomogram, based on the patient's height and sex. TBW may be reported by the patient, or obtained using a bed scale. LBW can be thought of as IBW plus 30% of the difference between TBW and IBW. In other words, for every pound or kilogram the patient is overweight, about one-third of this contributes to lean body mass.

POSTINTUBATION MANAGEMENT

The changes in the anatomy and physiology of obese patients have important implications for ventilator management. The initial TV should be calculated based on IBW and then adjusted according to airway pressures, with the success of oxygenation and ventilation indicated by pulse oximetry and capnography, or arterial blood gas monitoring. Generally, the use of at least 5 to 10 cm H_2O of PEEP is recommended to prevent end-expiratory airway closure and atelectasis. In severe obesity, it may be necessary to ventilate the patient in the semierect position to move the weight of the breasts, abdominal fat, or pannus off the chest wall.

Portable bedside radiographs are usually of poor quality in the obese patient, limiting their clinical value, although one can usually determine whether the ETT is in a mainstem bronchus.

TIPS AND PEARLS

- The predicted difficulty in BMV, EGD use, intubation, and cricothyrotomy combined with the decreased physiologic reserve in obese patients makes timely airway management important, and the decision to intubate cannot be delayed.
- For many obese patients, an awake technique, usually awake flexible endoscopy or video laryngoscopy, is the preferred method of intubation. If RSI is performed, rescue strategy should be well laid out, with the necessary equipment immediately available.
- Decreased FRC reduces adequate oxygen reserves and predisposes obese patients to rapid desaturation and hypoxemia. This may be mitigated with careful planning utilizing techniques such as head up or "ramped" positioning, NIV and PEEP for preoxygenation, good two-person BMV technique, and application of PEEP postintubation.

EVIDENCE

Is obesity an independent risk factor for difficult intubation?

Classically, morbid obesity has been described as an independent predictor of difficult intubation, but it is not clear whether it is obesity itself or more commonly described predictors of difficult intubation that contribute. Both neck circumference and increased BMI have been found to be independent predictors of difficult intubation. A recent large retrospective study of over 45 000 intubations found that although morbid obesity itself was not an independent risk factor for difficult intubation, it was a risk factor for difficult BMV.[1] Obesity also proves to be a risk factor for difficult intubation in the prehospital environment. In 2011, Holmberg et al.[2] found obesity to be an independent risk factor for difficult intubation after reviewing more than 800 prehospital intubations.

Is video laryngoscopy superior to direct laryngoscopy in obese patients?

Optimal positioning, as described earlier, will augment intubation attempts using any technique or device. Emergency department intubations are

overwhelmingly enhanced with video laryngoscopy (VL) compared with DL (see Evidence section of Chapter 16). A few studies have looked at video versus direct laryngoscopy (DL) in obese patients and found that video-assisted techniques result in significantly better glottic visualization. In morbidly obese patients, GlideScope laryngoscopy provided better glottic views and lower intubation difficulty scores compared with the Macintosh laryngoscope, with only slightly longer time to intubation.[3] Similarly, a randomized trial compared DL with three different VL devices in obese patients (Videomac, GlideScope, and McGrath) found that all three VL devices improved glottic view compared with DL. Video-Mac reduced time for successful placement of the tube, and both Video-Mac VL and GlideScope required fewer intubation attempts compared with DL and McGrath.[4]

What is the role of position for preoxygenation and apneic oxygenation in the intubation of the obese patient?

Not only intubation but also BMV is more difficult in obese patients. In addition, obese patients desaturate more rapidly than nonobese patients, making preoxygenation challenging as well. Positioning with the head elevated anterior to the shoulders aligning the external auditory meatus with the sternal notch or angle (Figure 43.1) has been shown to make both oxygenation and intubation easier.[5,6] Oxyhemoglobin desaturation was significantly delayed, and fewer patients desaturated < 90% when oxygen was continuously administered at 5 L/min by nasal cannula during the apneic phase of intubation.[7]

What is the role of NIV and recruitment maneuvers (RMs) in the obese patient?

Obese patients have greater risk for hypoxemia and atelectasis during induction and intubation, and some have advocated for further techniques, such as NIV and an RM, to improve oxygenation. NIV aims to increase the recruitment of collapsed alveoli and RM, which consists of a transient increase in inspiratory pressure after intubation (40 cm H_2O for 40 seconds), with a goal of decreasing atelectasis. This was evaluated in 66 morbidly obese patients randomized to three groups: conventional preoxygenation, preoxygenation with NIV, and preoxygenation with NIV +

postintubation RM. This study found that the combination of preoxygenation with NIV and RM improved Pao_2 and end-expiratory lung volume compared with conventional preoxygenation.[8]

Can ultrasound accurately identify the cricothyroid membrane in obese patients?

As described earlier, the increased neck circumference and impalpable landmarks can make an emergency cricothyrotomy challenging in the obese patient. A few studies have looked at the use of ultrasound to identify the cricothyroid membrane with promising results.[9,10] One randomized trial found that the use of ultrasound in human cadavers with poorly defined landmarks significantly reduced the complications (eg, laryngeal trauma) from 74% to 25% and increased the risk of a correct insertion by a factor of 5.[9]

What is the best method for BMV in obese patients?

As described above, BMV can be extremely challenging in the obese patients. A recent study examined the difference between the thenar grip technique for two-person BMV and the standard two-hand technique. This crossover randomized trial found that the thenar grip technique was more effective as defined by a higher TV during BMV.[11]

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CHAPTER 44

Foreign Body in the Adult Airway

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THE CLINICAL CHALLENGE

Foreign body airway obstruction (FBAO) presents a unique series of challenges. First, when incomplete obstruction is present, there exists the possibility that a particular action, or the failure to take specific action, could aggravate the situation by converting an incomplete obstruction into a complete obstruction. Second, when complete obstruction is present, instinctive interventions, such as bag-mask ventilation or insertion of an extraglottic device, have the potential to make the situation worse, for example, by causing a supraglottic obstruction to move below the cords making retrieval more difficult or impossible. Third, a common maneuver, such as the endotracheal intubation with bag ventilation, may meet with an unexpected result, such as the complete inability to move any air, defying the provider's attempts to find a solution to a problem perhaps never before encountered. Finally, the completely or partially obstructed airway is a unique clinical situation, unlike other airway threats, and requires a specific set of evaluations and interventions, often in a very compressed period of time.

The patient with FBAO may present with signs of upper airway obstruction or may present comatose and apneic, with only the history of onset to provide clues to the cause of the crisis. The obstruction may be complete, as in the patient who aspirates a food bolus and is unable to move

sufficient air to phonate. Although these situations usually arise in the out-of-hospital setting, they may occasionally present to the emergency department (ED), usually when an incomplete obstruction converts into a complete obstruction. An incompletely obstructing foreign body will cause symptoms and signs of partial upper airway obstruction, specifically stridor, altered phonation, subjective difficulty breathing, and often a sense of fear or panic on the part of the patient. In many cases, there will be a preceding condition that has increased the risk of aspiration. Many patients who aspirate food are physically or mentally impaired, elderly, or intoxicated with drugs or alcohol.

APPROACH TO THE AIRWAY

Management of the suspected or known adult FBAO follows a similar rationale to that used in the pediatric patient (see Chapter 28) and depends on the location of the foreign body and whether the obstruction is incomplete or complete. Location may be supraglottic, infraglottic, or distal to the carina. Because the precise location of the foreign body is typically not known, the following discussion first focuses on the approach to the foreign body whose location is uncertain and then discusses unique challenges in management of airway obstruction caused by tracheal foreign bodies.

Incomplete Obstruction by a Foreign Body

When the patient presents with an incomplete FBAO, the objective is to reestablish a fully patent airway and prevent the conversion of an incomplete obstruction into a complete obstruction. If the patient is cooperative and breathing spontaneously and if oxygen saturations are adequate (possibly with supplemental oxygen), then often the best approach is to have emergency airway equipment immediately accessible in case the patient deteriorates while efforts are made to rapidly mobilize the necessary providers for prompt removal in the operating room (OR). Some foreign bodies are obviously accessible and can be removed in the ED. There is risk with an incompletely obstructing supraglottic foreign body, however, that attempts at removal in the ED might result in displacement of the foreign body into the trachea, where it is no longer amenable to removal with

common ED instruments. If transfer to the OR is not an option (eg, because it would require transfer to another hospital), then a decision must be made as to whether the foreign body should be removed in the ED. In order to attempt retrieval of the foreign body in an incomplete FBAO, the first step may be handing the patient a rigid suction device (such as a Yankauer or DuCanto) hooked up to strong wall suction for attemps at self-retrieval. Patients can often feel where the foreign body is lodged and direct the suction to this area without gagging themselves.

If this approach fails, then the best approach is to handle the airway much as one would handle awake laryngoscopy for a difficult intubation (see Chapter 17). The operator assembles the appropriate equipment, preoxygenates the patient, explains the procedure, and administers topical anesthesia and, only if needed, a dissociative agent or titrated sedation, recognizing that either may trigger total obstruction. With the patient semisupine and anesthetized, the operator carefully inserts the laryngoscope with the left hand from the head of the bed, inspecting at each level of insertion before advancing to ensure that the foreign body is not pushed farther down by the tip of the laryngoscope. Either a direct or a video laryngoscope may be used, with preference for a device that allows both (such as a Macintosh-shaped video laryngoscope) because some foreign objects can be better evaluated with video and some with direct visualization. The technique is one of “lift and look,” followed by a small advance (perhaps 1 cm), and then another lift and look, and so on. It may be necessary to take a break to allow the patient to reoxygenate or to administer more topical anesthesia, dissociation, or sedation.

If the patient cannot tolerate a semisupine position, this technique can be modified with the patient sitting up and using the laryngoscope in a “face-to-face” position. In this scenario, the laryngoscopist typically holds the laryngoscope with the *right* hand so the flange is on the patient’s left, as it would be in a supine insertion. The laryngoscopist then uses the *left* hand to hold the foreign body removal instrument. Alternatively, a flexible endoscope can be used through the nose or mouth (with a bite block between the patient’s teeth to prevent scope damage) with the patient sitting up to visualize the foreign body. Once identified, however, a second operator is typically needed to handle the removal instrument.

When the foreign body is identified, the best instrument for removal (Magill forceps, tenaculum, or towel clip) is selected. Some foreign bodies, such as smooth-surfaced objects, may be difficult to grasp well with Magill forceps. After the object is grasped and successfully removed, laryngoscopy is again performed to ensure that no additional foreign body remains in the airway. The patient should then be observed until full recovery from the anesthesia has occurred to ensure that symptoms have resolved and that there are no other issues. Some patients may require a longer period of observation or admission to hospital if the provider suspects additional small foreign bodies below the vocal cords, significant aspiration, symptoms of upper airway edema after removal of the foreign body, or if there is concern about the patient's comorbidities (eg, chronic health issues and intoxication). Additionally, first-aid foreign body expulsion maneuvers, such as the abdominal thrust (ie, Heimlich maneuver), occasionally cause major thoracoabdominal injuries. Therefore, patients who received a first-aid foreign body expulsion maneuver should be carefully evaluated, and the provider should have a low threshold to obtain radiographic or computed tomographic studies to evaluate the extent of injuries. Acute incomplete FBAO should always be considered a true emergency, and an early decision is required regarding the appropriateness of removal in the ED versus expedited transfer to the OR. If, at any point, the airway becomes completely obstructed, then the patient is managed as described in the following section.

Complete Obstruction of the Airway

When airway obstruction is complete, the patient is unable to breathe or phonate and may hold his or her neck with one or both hands, the so-called universal choking sign. The patient may appear terrified and will be making attempts at inspiration. In general, after complete obstruction of the airway with ensuing apnea, oxygen saturation will fall rapidly to levels incompatible with consciousness.

Initial management is dictated by whether the patient is conscious or unconscious. If the patient is conscious, the latest guideline from the International Liaison Committee on Resuscitation (ILCOR) recommends performing back slaps initially in adults and children with a complete

FBAO, then abdominal thrusts if back slaps are ineffective. The abdominal thrust should be repeatedly administered until either the foreign body is expelled or the patient loses consciousness. There is no point in attempting instrumented removal of an upper airway foreign body while the patient is still conscious, as a struggling and uncooperative patient in extremis will likely result in inability to grasp the foreign body or, even worse, displacement of the foreign body further down the airway. If the abdominal thrust is successful in expelling the foreign body, and the patient can phonate and breathe normally, then observation for a few hours is sufficient, and it is not mandatory to visualize the airway if the patient remains asymptomatic. If the abdominal thrust is unsuccessful in removing the foreign body and the patient loses consciousness, a rapid series of chest thrusts (equivalent to those used during cardiopulmonary resuscitation [CPR]) may be tried.

Thereafter, the first step is immediate direct or video laryngoscopy *before any attempts at bag-mask ventilation, which may cause the foreign body to move from a supraglottic to an infraglottic position* (see algorithm, **Fig. 44.1**). If the patient is flaccid, which is typically the case, then no sedation or neuromuscular blocking agent is needed to perform laryngoscopy. Time should not be lost waiting for an intravenous line to be established.

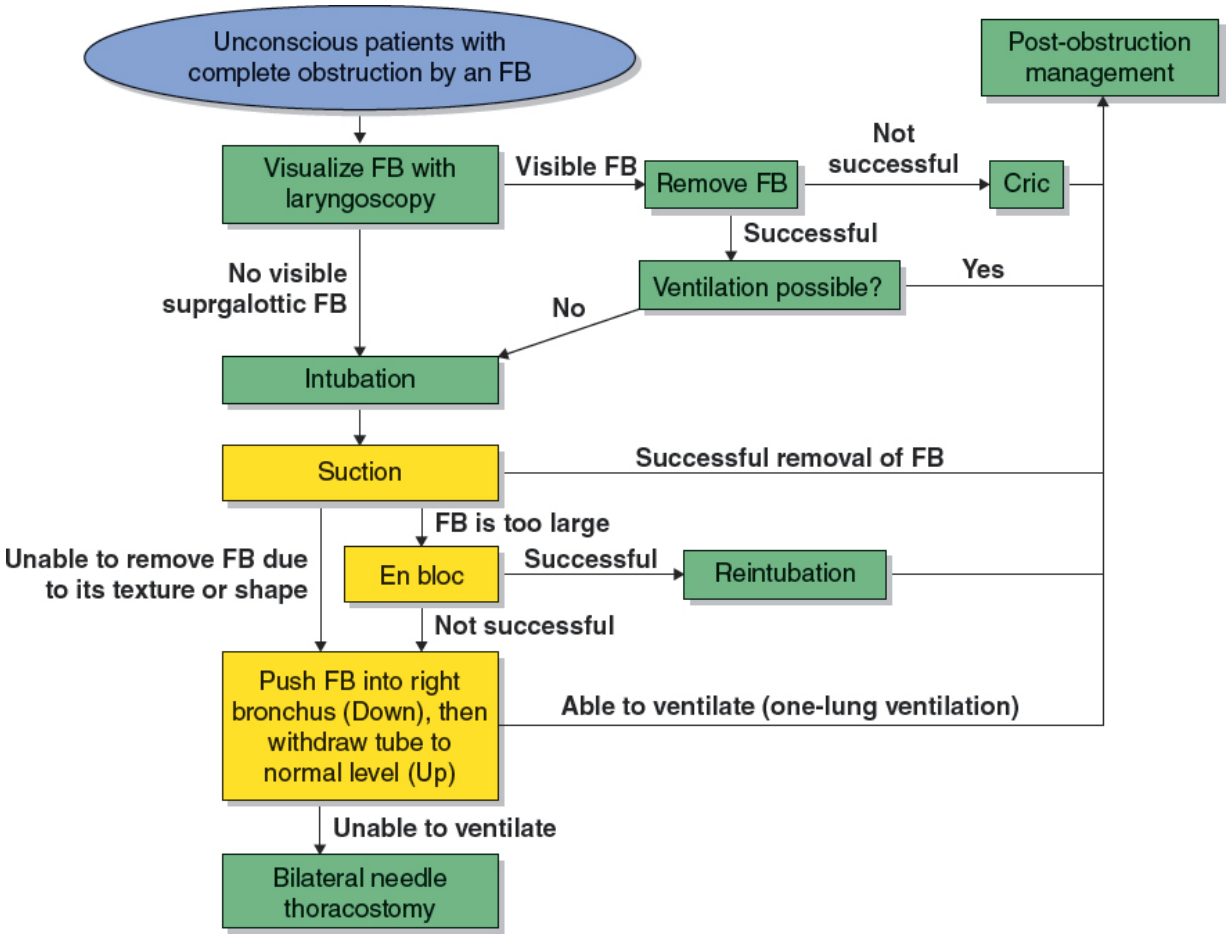

Figure 44.1: Management of complete obstruction by a foreign body. Cric, cricothyroidotomy; FB, foreign body. See text for explanation.

Supraglottic Obstructing Foreign Body

With direct or video laryngoscopy, an obstructing foreign body above the glottis is easily identifiable. Magill forceps, a tenaculum, a towel clip, or any other suitable instrument can be used to remove the foreign body. After the foreign body has been removed, the larynx must be thoroughly inspected to ensure that there is no residual foreign material. When the foreign body is removed, the patient may begin spontaneous ventilation immediately. If the patient does not begin to breathe spontaneously, immediate intubation and initiation of positive-pressure ventilation is indicated and can be performed during the same laryngoscopy (Fig. 44.1). In the event the foreign object cannot be removed, immediate cricothyroidotomy should be performed to try to establish an airway below the level of the obstruction. If laryngoscopy does not identify a foreign

body, and the glottis is clearly visualized, then either there is no foreign body or the foreign body is below the vocal cords. In this case, the patient should be immediately intubated and ventilated. If ventilation is successful, then resuscitation proceeds as for any other patient. If bag ventilation through the endotracheal tube (ETT) meets with total resistance (no air movement and no end-tidal carbon dioxide detection), then the trachea is completely obstructed and requires techniques unique to tracheal complete FBAO.

Tracheal Complete Foreign Body Airway Obstruction

With a complete FBAO in the trachea, there are three techniques that should be performed sequentially (Fig. 44.1). The first technique is to remove the foreign body with vigorous suction. After intubation and stylet removal, a neonatal meconium aspirator (Neotech Products, Inc., Valencia, CA) may be directly attached to the bag connector of the ETT and then connected to continuous wall suction. This allows the operator to control suction by occluding the side hole of the meconium aspirator with a fingertip and use the ETT as a large-bore suction catheter. This works best when the ETT distal end is precut to 90 degrees, removing the bevel and Murphy eye so that a “vacuum cleaner” effect can occur at the end of the ETT (see **Fig. 44.2**). A similar technique is often performed for the massively soiled airway (see Chapter 41). This approach is effective when the foreign body is small; however, it would be unsuccessful when the foreign body is larger than the diameter of the endotracheal lumen. In that case, the operator needs to proceed to the second technique.

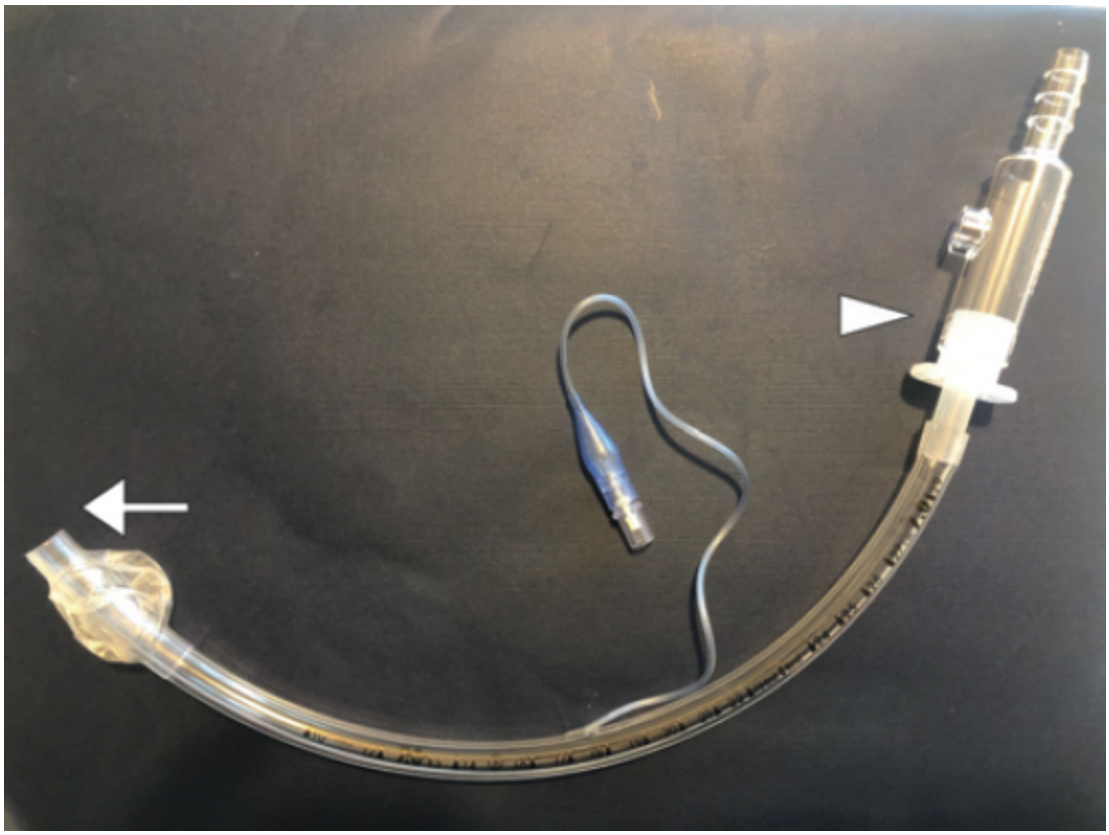

Figure 44.2: Endotracheal tube (ETT) with a neonatal meconium aspirator. A meconium aspirator is directly attached to the bag connector of the ETT (arrowhead). The ETT distal end is precut to 90 degrees (arrow).

The underlying idea of the second technique is to remove the FB together with the ETT altogether, if the suction “catches” the foreign body but cannot pull it through the lumen of the ETT. To perform this en bloc technique, the operator applies continuous suction, holds the foreign body against the distal tip of the ETT (vacuum cleaner effect), removes everything together, and then reintubates the patient. This technique requires the operator to perform extubation and reintubation and should be performed only when the foreign body is felt at the tip of the ETT and the foreign body cannot be removed with the first method owing to the size or viscosity of the foreign body. When the aforementioned techniques fail, the operator would be forced to attempt the third technique.

The third technique, known as a “down-then-up” approach, is to push the foreign body into a mainstem bronchus by advancing the ETT (down), then withdrawing the ETT into the midtrachea (up). The operator advances the ETT as far down as possible in an attempt to push a tracheal foreign

body into the right (or left) mainstem bronchus. If the foreign material is thought to be soft, then an attempt at ventilation can be made with the ETT inserted to its deepest extent, on the basis that the ETT may have passed through the obstruction. If ventilation is not successful, then the foreign body is assumed to be solid and to have been pushed into the mainstem bronchus ahead of the ETT. The tube is then withdrawn to its normal level, the cuff is inflated, and ventilation is attempted. The strategy here is to try to convert an obstructing tracheal foreign body (which will be lethal) to an obstructing mainstem bronchus foreign body (which can be removed in the OR). Thus, the patient can be kept alive by ventilating one lung while the other lung is obstructed.

If all techniques described are not successful, there are two clinical possibilities. The only reversible situation is when the patient has one obstructed mainstem bronchus and a tension pneumothorax on the other side. Pneumothoraces can occur in FBAO cases because of the abnormally high pressures generated both by the patient, while conscious, and by the rescue maneuvers. Because the operator has no way of knowing into which mainstem bronchus the foreign body was advanced (most commonly the right, but possibly the left), bilateral needle thoracostomy should be performed, in the hope of identifying a tension pneumothorax. If a pneumothorax is not identified, the second clinical possibility is complete bilateral mainstem obstruction, a condition from which survival is not possible regardless of treatment.

POSTINTUBATION MANAGEMENT

Postintubation management depends on the clinical circumstances. If the foreign body has been successfully removed and the patient remains obtunded, perhaps from post-hypoxemic encephalopathy, then ventilation and general management are as for any other postarrest patient. If the foreign body has been pushed down into one mainstem bronchus, the other lung must be ventilated carefully at low rates with reduced tidal volumes to minimize the risk of barotrauma while waiting for the OR. As stated previously, patients who received first-aid foreign body expulsion maneuvers should be carefully evaluated for any internal injuries.

TIPS AND PEARLS

- If the patient has an incomplete FBAO and is stable, the best approach is, typically, to wait for definitive removal in the OR under a double setup. If you are forced to act, move cautiously and deliberately to ensure that you do not convert a supraglottic obstruction into an infraglottic obstruction.
- If there is a complete FBAO above the vocal cords that cannot be removed, cricothyrotomy is indicated.
- If there is a complete FBAO below the vocal cords and it cannot be seen from above by direct laryngoscopy, it is extremely unlikely that cricothyrotomy will place an airway below the level of the obstruction, and therefore cricothyrotomy is not indicated.
- If the patient is unconscious and does not regain spontaneous ventilations when supraglottic foreign bodies are cleared, then perform tracheal intubation.
- A decision to choose the most suitable technique for cases with complete tracheal FBAO may best be made based on the size and characteristics of the foreign body and the operator's comfort level with the techniques. However, the technique of vigorous suction by using an ETT as a large-bore suction catheter should be attempted before other techniques.
- If ventilations are impossible through the ETT, then the "down-then-up" maneuver should be performed with the ETT with hopes of advancement of an obstructing tracheal foreign body into a mainstem bronchus, withdrawal of the ETT to its usual midtracheal position, and oxygenation and ventilation of the other lung.

EVIDENCE

When should I use abdominal thrust maneuvers versus back blows?

There are no quality studies comparing the effectiveness of various methods for expelling an obstructing foreign body. There is no clear evidence to establish the superiority of chest compressions over abdominal thrusts or vice versa. The American Heart Association (AHA), in its 2010 guidelines

for emergency cardiac care, recommended a progression of airway clearing maneuvers in the conscious patient, beginning with back blows and progressing to abdominal thrusts.[1] There was no significant change to this approach in the 2020 AHA guideline update. If the abdominal thrust maneuver is not successful despite repeated attempts, and the patient is unconscious, then chest thrusts can be tried, but there is no evidence that they will be more successful than abdominal thrusts. For obese patients or women late in pregnancy, chest thrusts are preferred. A cadaver study indicates that greater airway pressures can be developed using chest thrusts than with abdominal thrusts when the patient is unconscious, and this evidence is reflected in the AHA recommendations.[2]

Are antichoking suction devices effective to remove a foreign body from the airway?

In contrast to standard first-aid foreign body expulsion maneuvers (eg, the abdominal thrust) that create positive pressure in the thoracic cavity to expel a foreign body from the airway, maneuvers that produce negative airway pressure from above in order to remove a foreign body have gained attention recently. Antichoking suction devices have become commercially available, and there are several small case series that showed the efficacy of the devices.[3] Even the use of a home vacuum cleaner for this purpose has been reported.[4] However, the strength of evidence is constrained by the small sample sizes of the studies and methodologic limitations. The latest ILCOR 2020 Consensus on Science and Treatment Recommendations (CoSTR) for BLS recommends against the *routine* use of suction-based airway devices.

What evidence is available on the effectiveness of advanced techniques beyond first-aid maneuvers to relieve FBAO?

One observational study of supraglottic FBAO found that the use of Magill forceps in the prehospital setting was effective. The study included 240 adults and children with out-of-hospital cardiac arrest (OHCA) with FBAO. In the multivariate analysis, the study found that Magill forceps use for OHCA with FBAO was associated with better neurologically favorable survival compared with no use (OR, 3.96 [95% CI, 1.21-13.00]). This evidence is reflected in the 2020 CoSTR recommendations.[3] In contrast, the

available evidence in the management of FBAO secondary to infraglottic foreign bodies is extremely limited. There are only a handful of papers that have described the success of various techniques.[5,6]

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CHAPTER 45

Safe Extubation in the Emergency Airway Patient

Matteo Parotto

THE CLINICAL CHALLENGE

Extubation is an uncommon procedure in emergency medicine. However, certain scenarios, such as a rapidly recovering polysubstance overdose patient, may make extubation desirable. Complications at extubation continue to occur and account for nearly one-third of reported major airway complications, as evidenced by the fourth National Audit Project (NAP4). These findings led to the development of guidelines from several scientific societies (see Evidence section). Although these guidelines focus on perioperative and critical care medicine, many of the principles of a comprehensive planned approach to extubation apply to emergency populations as well. Emergency physicians may be increasingly involved in the extubation process as intubated patients spend longer durations in the emergency department (ED). Extubation is a vital component in airway management and requires the same meticulous planning and communication involved with intubation. Like intubation, recognition of the potentially difficult extubation is instrumental in the planning process. Emergency physicians should be familiar with recognition of the potentially difficult extubation, creation of an extubation strategy, and execution of a safe extubation.

PLANNING FOR EXTUBATION

Consider a morbidly obese 55-year-old restrained driver who is brought into the ED from a single-passenger, single-vehicle incident 30 minutes prior during severe winter weather. He was intubated in the field because of

decreased level of consciousness. Four attempts using both direct and video laryngoscopy were required secondary to a cervical collar, short neck, and redundant soft tissue. Computed tomography (CT) scan reveals a single lung contusion but no rib fractures, flail segment, or other significant injuries. The patient's hemodynamics are within normal limits and, aside from a high blood alcohol level, initial and repeated blood work results are stable. It is now 8 hours since the incident, and the patient remains in the ED. He is responsive to command, moving all extremities, and is becoming more agitated, requiring soft restraints and escalating doses of sedation. His tongue is large and bruised. Some bruising was noted over the anterior chest on secondary survey. Vitals remain stable, and an arterial blood gas on minimal vent settings (pressure support with an FIO_2 of 30%) shows a PaO_2 of 100 mm Hg, O_2 saturation of 98%, and PCO_2 of 43 mm Hg. There are no available ICU beds, and you now need to either extubate him or escalate his sedation (**Fig. 45.1**). How should you proceed?

Figure 45.1: Intubated morbidly obese 55-year-old restrained driver brought into the emergency department.

EXTUBATION CRITERIA

Fortunately, there are defined general principles to follow when considering extubating a patient. Unlike intubation, extubation is *always* an elective procedure and should therefore be pursued only if and when the physiologic, pharmacologic, and contextual conditions are optimized. In a busy ED, there are always the pressures of time and bed space. A written checklist approach can facilitate a patient's readiness for extubation. **Table 45.1** highlights minimum recommendations to consider when evaluating a patient for extubation. Having a consistent, predictable approach should be the overall goal to reduce the incidence of extubation failure.

TABLE 45.1 Extubation Criteria

Reversal of underlying process	• No further need for mechanical ventilation identified • No expected need in immediate hospital course
Level of consciousness	• Alert patient • Sedation medications discontinued
Ability to oxygenate	• Spontaneous breathing • Tidal volume > 5-7 mL/kg • SpO_2 > 92 with F_{IO_2} 30
Ability to ventilate	• Positive end-expiratory pressure < 8 mm Hg • Peak voluntary negative pressure >20 cm H_2O
Predictors of impending airway loss	• Protecting own airway • Reversal of neuromuscular blockade (train of four > 90) • peak expiratory flow > 60 L/min (cough assessment) • Difficult intubation? • Difficult bag-mask ventilation?
Pulmonary secretions	• Oropharyngeal secretions minimal

	• Risk of aspiration minimal

RISK STRATIFICATION

Once the decision to extubate has been made, the focus shifts to the identification of those airways that may be at increased risk for extubation failure, which comes at the cost of an increased risk of difficult intubation, prolonged intensive care unit (ICU) stay, increased cost, and increased mortality. The Difficult Airway Society recommends risk-stratifying patients into *low risk* versus *high risk* for extubation failure (see **Tables 45.2 and 45.3**). This is discussed further in the Evidence section later. This helps to narrow the focus to the *at-risk* group in order to identify those patients who require additional planning; however, it remains important to remember that care must be taken with tracheal extubation, even in patients identified as low risk. Some of the general risk factors that are highlighted in the at-risk group for extubation are listed in Table 45.3.

TABLE 45.2 Difficult Airway Society Risk Stratification

Low risk	• Fasted? • Uncomplicated airway • No general risk factors
At risk	• Ability to oxygenate uncertain • Reintubation potentially difficult • General risk factors (Table 45.3)

From Mitchell V, Dravid R, Patel A, et al. Difficult Airway Society Guidelines for the management of tracheal extubation. Anaesthesia*. 2012;67(3):318-340.*

TABLE 45.3 General Risk Factors

Airway risk factors	• Known difficult airway • Airway deterioration (trauma, edema, bleeding) • Restricted airway access • Obesity/obstructive sleep apnea • Aspiration risk

General risk factors	• Cardiovascular • Respiratory • Neurologic • Metabolic • Special surgical requirements • Special medical requirements

Pay special attention to the airway risk factors section, because this can be difficult to identify prior to extubation. In addition to laryngeal irritation from the indwelling tracheal tube, postintubation interventions, such as extensive fluid resuscitation, may have resulted in airway edema and could increase the risk of postextubation airway obstruction. Anticipated disease course must also be considered. For example, burns or soft tissue infections to the face or neck may be more difficult to reintubate than initially recorded.

Extubation failure is usually attributable to one of two issues, or both: upper airway obstruction or recurrent respiratory failure. Upper airway obstruction, including laryngospasm, is associated with immediate respiratory distress and hypoxemia. On the other hand, recurrent respiratory failure, or a gradual decline in the ability of the patient to breathe on his or her own without support, is a much more common issue in the ICU. Immediate upper airway collapse and obstruction is more common in the postoperative setting than in the ICU, but recurrent respiratory failure remains the most common cause of the need to reintubate the patient. In emergency medicine, the characteristics of patients failing extubation are unknown. Patients that may be extubatable in the ED, however, such as a patient intubated for airway protection after an overdose may be at risk for respiratory failure if they have a severe aspiration pneumonitis. Thus, it is important to consider the past (what led to the intubation and how difficult was it?), the present (can they protect their airway and maintain gas exchange now?), and the future (are they at risk for obstruction, or respiratory failure, and how difficult would the reintubation be?)

ADDITIONAL TESTING

In patients with an *at-risk* airway, one must first decide whether extubation should even be attempted in the ED. If after taking into consideration the

patient's high-risk features, intubation history, and availability of difficult airway equipment and support, extubation is feasible and prudent, then additional testing may help reassure safety enough for extubation. A cuff leak test may be performed to assess the risk of upper airway obstruction after removing the tracheal tube (see **Box 45.1**). A cuff leak test predicts postextubation stridor in children intubated for croup. In adults, a cuff leak alone does *not* necessarily predict success of extubation but can be used with several other criteria to judge the likelihood of success (see Evidence section).

BOX 45.1 Cuff Leak Test

- ***What is the cuff leak test?*** The cuff leak test is used to predict the population that may be at increased risk for post extubation stridor. It is a measurement of the cuff leak volume, which is equal to the difference between the inspiratory tidal volume and the average expiratory tidal volume while the cuff around the endotracheal tube is deflated.
- ***How is it performed?*** Variable methodologies are described in the literature. The most common is to set the assist control mode with the fixed tidal volumes of 10 to 12 mL/kg. The inspiratory tidal volume with the cuff inflated is then measured. The cuff is then deflated, and a brief period of coughing usually proceeds. Following the resolution of coughing, four to six breaths are given, and the average value of the three lowest expiratory tidal volumes is computed. The difference between the inspiratory tidal volume with the cuff inflated and the averaged expiratory tidal volume with the cuff deflated is used to calculate the cuff leak volume.
- ***Application to practice:*** The cuff leak volume of <130 mL is generally accepted as indicating a cuff leak is absent (positive test) and places the patient at risk for postextubation stridor and extubation failure. The absence of a cuff leak should therefore alert the airway manager to the potential for a postextubation complication, and a plan should be devised accordingly.

A cuff leak occurs when exhaled air goes around the endotracheal tube (ETT) when the cuff is deflated and is exhaled through the glottis. An absent cuff leak can occur when there is no space between the tube and the airway mucosa at any level, whether it be from a large ETT against the trachea or laryngeal edema at the glottic opening. Check a cuff leak in patients at high risk, which include those with a difficult intubation; those intubated with a large ETT, or large ETT for height; those intubated >3 days; or women (they are more likely to have a large ETT for height). An absent cuff leak is concerning for potential postextubation stridor and, therefore, the potential for airway obstruction.

If absent, published guidelines suggest administering a dose of steroids, followed by a delayed extubation attempt. Another option is to visualize the airway for laryngeal edema. The airway can be evaluated by direct laryngoscopy, video laryngoscopy, or nasopharyngoscopy. Nasopharyngoscopy can be achieved with a pediatric bronchoscope or a nasopharyngoscope and application of local anesthetic nasally (3-4 sprays of 4% lidocaine would typically suffice). If nasopharyngoscopy is chosen, the patient should be sitting up and asked to flex his or her neck forward ("like a chicken") to maximally open the hypopharyngeal space and allow for best visualization. The ETT cuff can be deflated, and breathing around the ETT can be assessed by direct inspection. Video laryngoscopy has the advantage of creating a "shared mental model," with health care professionals taking care of the patient being able to also visualize the airway. Topicalization of the posterior pharynx, including the vallecula, is usually required for either video or direct laryngoscopy. Sedation may also be required. Assessment of cough can also be completed by performing a peak expiratory flow. Values of less than 60 L/min have been associated with an increased incidence of extubation failure.

PROCESS OF EXTUBATION

General Extubation

Extubation is always an elective procedure that should be planned and prepared for. Overall, the goal should be maintenance of oxygenation and ventilation, and a comprehensive plan in the event extubation failure occurs. An awake, spontaneously breathing patient can accomplish several

of the overall goals during extubation independently. They can protect their airway, maintain patency with muscular tone, and facilitate gas exchange with spontaneous breathing. This is significantly different from the heavily sedated patient. For this reason, extubation is generally recommended in an awake state. This corresponds well with the extubation criteria highlighted in Table 45.3. The general process of extubation in a *low-risk* situation follows the stepwise process described in **Table 45.4**.

TABLE 45.4 General Steps
1. Extubation criteria met (Table 45.5)
2. Deliver 100% oxygen
3. Suction of airway
4. Insert soft bite block
5. Position patient with head up
6. Untie/tape tube
7. Deflate cuff
8. Apply positive pressure while removing endotracheal tube
9. Transfer to face mask
10. Confirm continued ventilation/oxygenation

Complications

Most low-risk extubations are completed without significant complications. However, vigilance during this period of transition from a controlled situation is imperative because hypoxic insults are not uncommon during this time. Complications that can occur during extubation are listed in **Table 45.5**. A component in the planning process for extubation is to mitigate the risk factors that lead to complications. Even with the low risk, one should still be able to handle the complications of extubation should they occur (**Box 45.2** and **Table 45.6**).

TABLE 45.5 Extubation Complications
Hypoventilation

Upper airway obstruction
Laryngospasm (Box 45.2)
Bronchospasm
Vocal cord damage
Negative pressure pulmonary edema
Pulmonary aspiration
Coughing
Hemodynamic alterations (tachycardia, hypertension, dysrhythmias, acute coronary syndrome)

BOX 45.2 Laryngospasm

- ***What is laryngospasm?*** Laryngospasm is an exaggerated prolongation of the normal glottis closure reflex triggered by mechanical or chemical (aspiration, secretions) stimulus.
- ***What are the risk factors?*** The risk factors for laryngospasm can be broken into patient or procedure factors. Patient factors that increase the risk of laryngospasm include young age (children), smokers, and recent respiratory infection. Procedural factors include airway manipulation (intubation/extubation), stimulation during the transition period between deep anesthetic/awake state and the presence of debris in the airway (blood, secretions).
- ***Management:*** The first step in management is reduction of the risk factors associated with laryngospasm. This includes suctioning of the airway prior to extubation and avoiding extubation when transitioning from the plane of deep anesthetic to awake state. If laryngospasm does occur, prompt recognition followed by treatment is imperative (Table 45.6).

TABLE 45.6 Treatment of Laryngospasm

1. Call for help.
2. Apply continuous positive pressure and administer 100% F_{IO_2} in an attempt to “break” spasm.

3. Larson's maneuver: place middle fingers posterior to mandible and anterior to mastoid process. Combine with jaw thrust forward.
4. Low-dose propofol 0.25 mg/kg, if persists high-dose propofol 1-2 mg/kg
5. Succinylcholine 1 mg/kg IV if severe hypoxia, with persistent cord closure if propofol ineffective. Consider atropine 1 mg should bradycardia occur.
6. No resolution? Failed airway algorithm

ADJUNCTS TO EXTUBATION

Airway Exchange Catheter

Patients deemed at *high risk* of extubation failure may require adjuncts as part of an airway plan. A common technique is the use of an airway exchange catheter (AEC) for maintenance of continuous access to the airway. AECs are thin, hollow tubes with a blunt end located distally. They are supplied with a 15-mm connector compatible with a breathing circuit as well as luer lock connectors for high-pressure (jet) ventilation (**Fig. 45.2**). Although leaving an AEC in the trachea is an “off-label” application of these devices (they were originally designed to facilitate ETT exchange), it is supported by expert opinions and scientific societies when used as described next.

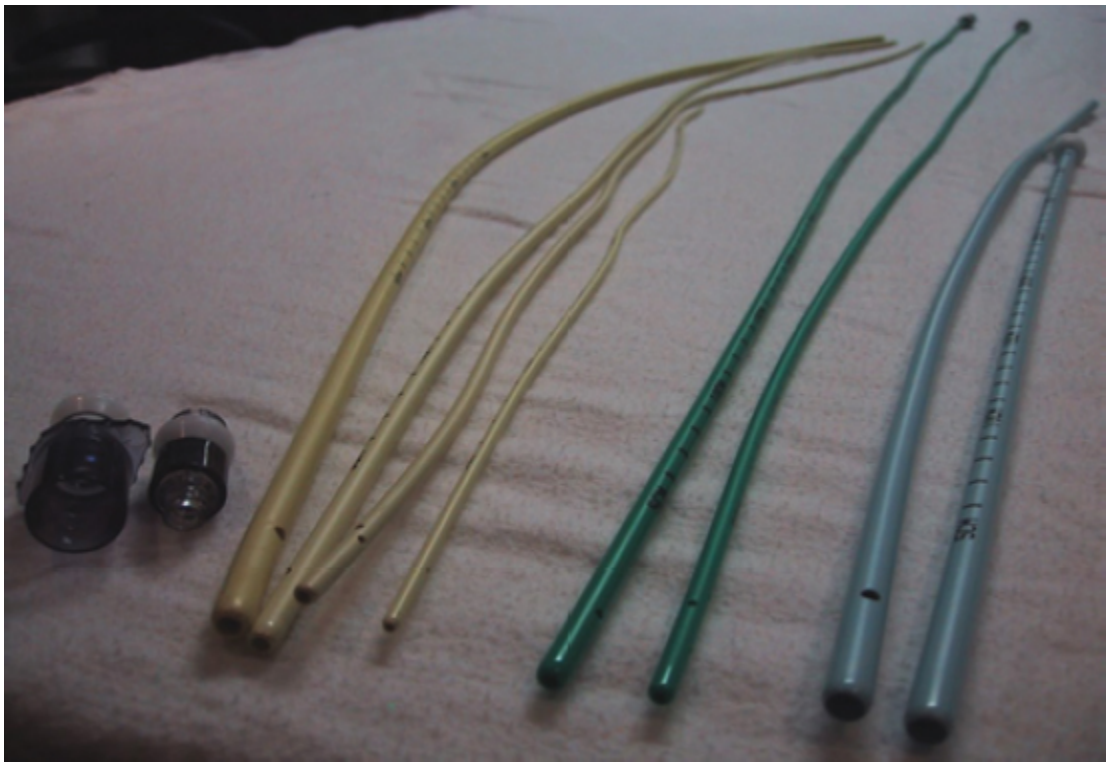

Figure 45.2: Examples of airway exchange catheters, Aintree catheters, and Rapid Fit connectors.

The most commonly available AECs are made by Cook Medical (Bloomington, Indiana, www.cookmedical.com). The Cook 11F and 14F AECs are commonly used in adults, are well tolerated in the awake patient, and are compatible with ETTs with internal diameters greater than 4 and 5 mm, respectively; 19F AECs are also available, but are tolerated only in awake patients 50% of the time. For all AECs, tolerance depends on keeping the tip of the AEC above the carina. Therefore, the numbers on the AEC should be aligned with the ETT numbers accordingly. No lidocaine is required through or around the AEC because this has not been shown to increase tolerance of the device. Patients can phonate with an 11F or 14F AEC in place. The method for using an AEC is highlighted in **Table 45.7** and **Figure 45.3**.

Figure 45.3: Patient with airway exchange catheter taped to forehead. Note the use of face mask for supplemental oxygen. (Reprinted by permission from Springer Nature: Duggan LV, Law JA, Murphy MF. Brief review: supplementing oxygen through an airway exchange catheter: efficacy, complications, and recommendations. *Can J Anesth*. 2011;58(6):560-568.)

TABLE 45.7 Airway Exchange Catheter (AEC)

1. Selection of AEC 11F or 14F.
2. Decide how far to insert AEC. If any doubt that tip will lie above carina, examination of endotracheal tube depth should be completed with a flexible endoscope prior to insertion.
3. Oxygen insufflation through the catheter should NOT be used except in life-threatening situations by an expert trained in the technique. Use alternative methods for oxygenation.
4. Insert lubricated catheter through endotracheal tube to predetermined depth (usually 20-22 cm). Never advance against resistance.
5. Oropharyngeal suctioning prior to removal.
6. Proceed with extubation over AEC while maintaining in fixed position.
7. Secure AEC in place with tape on side of mouth/forehead (Fig. 45.3).
8. Transfer to face mask with capnography for detection of possible obstruction.
9. Clearly label AEC so as not to be confused with nasogastric tube.
10. If extubation fails, reintubate over catheter with either direct or video-assisted laryngoscopy (Table 45.8).

Complications associated with AECs include pneumothorax, pneumoperitoneum, hypoxia during airway management, perforation of the lower airways, and unintended esophageal misplacement potentially also leading to perforation. Supplemental oxygen postextubation should be maintained with a face mask, nasal prongs, or continuous positive airway pressure (CPAP), although oxygen insufflation and jet ventilation through an AEC is possible. The use of oxygen insufflation and jet ventilation through AEC can be complicated by life-threatening barotrauma and should be avoided except in a can't intubate and can't oxygenate (CICO) situation. If this occurs, low flow rates (1-2 L/min) while prepping the neck for surgical airway access are preferred.

The timing to remove an AEC postextubation is the subject of much debate and should be individualized to the patient's respiratory reserve,

potential for difficult reintubation, and clinical course. They can be left in the airway for 24 hours and longer.

Reintubation over an AEC should be performed using a video laryngoscope because it has a higher first-pass success rate when compared with direct laryngoscopy. Railroading an ETT over an AEC *without* a laryngoscope, either video or direct laryngoscopy, is associated with a high failure rate, including dislodgment of the AEC.

The patient should be in the semisitting position to allow for soft tissues to fall away from the glottis. Suction is useful prior to and during reintubation and should be readily accessible. The patient's head should be extended, if possible. The operator should be high above the head of the bed, either on step stools or the bed frame (this also gets the attention of everyone in the room!). Reintubation can be performed with topicalization only, sedation, or complete induction. Dexmedetomidine (Precedex) can be a useful adjunct, especially in the agitated patient. **Table 45.8** highlights a sequence for the use of AEC for resecuring the airway. Like the approach to intubation, a well-laid-out plan in the event of failure is crucial.

TABLE 45.8 AEC for Reintubation (Difficult Airway Society Algorithm)

1. Position of patient: sitting up as much as possible; oro- and hypopharynx suctioned
2. Apply 100% oxygen with CPAP via face mask, or apply high-flow nasal prongs.
3. Select small endotracheal tube with soft tip blunt tip.
4. Administer anesthetic or topicalization as indicated.
5. Use direct or indirect laryngoscopy to retract the tongue and railroad the endotracheal tube (with bevel facing anteriorly) over the AEC.
6. Confirm position of the tube with capnography if time allows.

AEC, airway exchange catheter; CPAP, continuous positive airway pressure.

An ETT size that "hugs" the sides of the AEC should be chosen. In other words, this is a time for oxygenation, not preferences for a larger ETT. The proximity between the sidewalls of the AEC and the inner wall of the ETT will make the difference between success and failure of this technique.

If there is a significant space between them, the glottic structures can become “hung up” in this space, preventing passage of the ETT and potentially dislodging the AEC. Solutions to this issue include choosing a smaller ETT size or “increasing” the size of the AEC with an Aintree© catheter (**Fig. 45.4**).

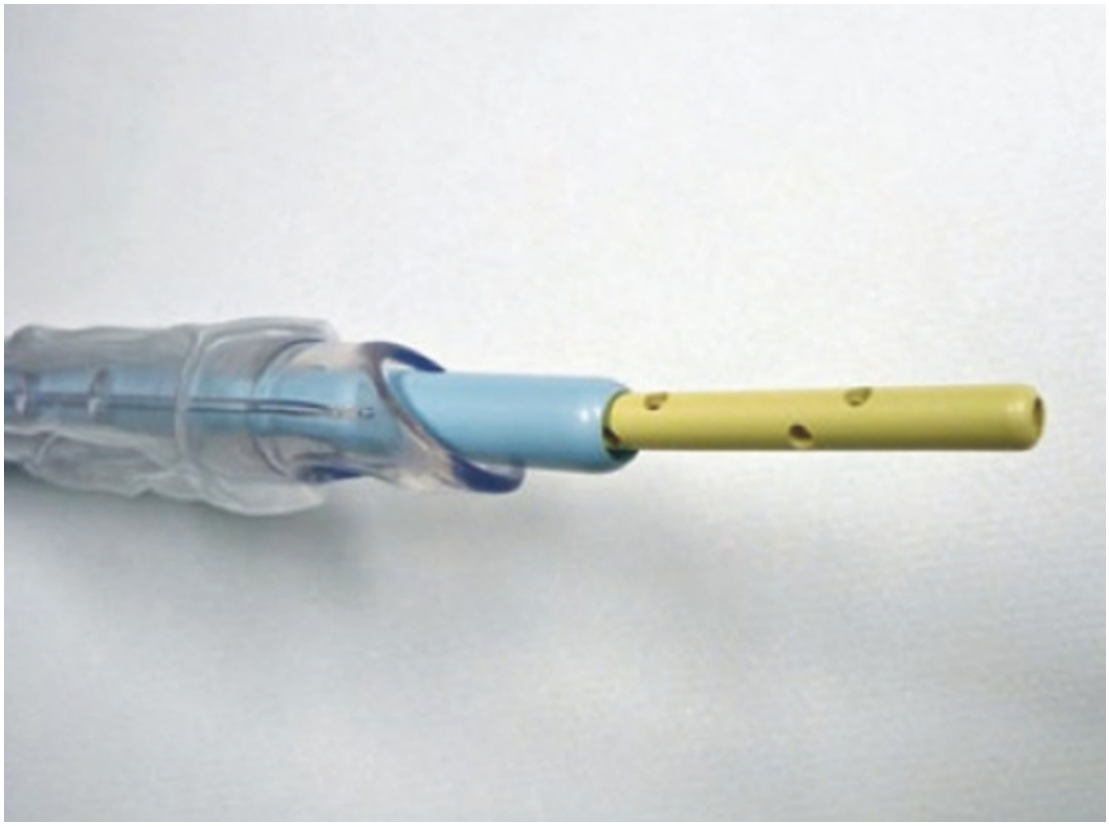

Figure 45.4: 11F Airway exchange catheter (AEC) sheathed in Aintree© 19F catheter to assist in preventing soft tissues from catching between the AEC and endotracheal tube. (From Law JA, Duggan LV. Extubation guidelines: anaesthetists’ use of airway exchange catheters. *Anaesthesia.* 2012;67(8):918-919.)

As the glottis is reached with the ETT, a counterclockwise twist of the ETT will aid in its passage. The leading edge of the ETT is on the right side of the ETT, and this will move it away from the right-sided glottic structures. Small maneuvers such as the ones described previously will increase the success rate of reintubation over an AEC. Finally, like any other procedure, the use of an AEC as part of a staged extubation plan requires some experience and practice. The authors recommend inviting

anesthesia or ICU colleagues with experience using these devices for consultation until the practitioner is comfortable.

NONINVASIVE VENTILATION AND HIGH-FLOW NASAL OXYGEN

Extubation to noninvasive ventilation (NIV) has been evaluated in the adult ICU population as a useful adjunct in individuals at increased risk for failure, especially in patients with chronic obstructive pulmonary disease (COPD), obesity, and high-risk features for extubation failure (see Evidence section). Immediate application of bilevel positive airway pressure (BiPAP) following extubation with initial inspiratory positive airway pressure ranging from 8 to 16 cm H_2O and expiratory positive airway pressure ranging from 4 to 6 cm H_2O is recommended. The settings are then adjusted according to PaO_2 and $PaCO_2$. If used, a minimum of 24 hours is required to confer benefit. It is still unknown whether the short-term application of nasal intermittent positive pressure ventilation as an adjunct to ED extubation results in decreased failure rates. However, owing to the overall benefits demonstrated in the ICU population, and the postoperative benefits for obstructive sleep apnea and obese patients, consideration for extubation to BiPAP should be included as part of the airway plan when clinically indicated.

Studies have shown that high-flow nasal oxygen applied after extubation may reduce reintubation rates in ICU patients at low risk for extubation failure, and this approach may be considered when indicated (see Evidence section).

SEDATION DURING EXTUBATION

Intubation and positive pressure ventilation can be uncomfortable for patients, leading to ventilator dyssynchrony, potential patient and health care worker safety issues (and the need for physical or chemical restraints). The goal during extubation is a calm cooperative patient who can follow commands and can meet their own respiratory requirements. Postextubation sedation should be considered carefully, weighing multiple factors such as the patient’s agitation and delirium, high-risk features, and access to

appropriate medications. If sedation is required, agents that facilitate patient compliance yet have minimal effect on ventilatory drive and protective airway reflexes should be used. Dexmedetomidine has been found to be helpful in the management of postextubation agitation and delirium and, unlike many other sedative agents, does not negatively influence respiratory drive.

In the scenario presented at the beginning of the chapter, the patient was able to follow commands but was intermittently agitated. Dexmedetomidine infusion was begun with 1 µg/kg/hour for the first hour, then decreased to 0.5 µg/kg/hour thereafter in order to facilitate cooperation. The patient was sitting up, and the oropharynx and ETT were suctioned. There was a cuff leak on quantitative assessment of >130 mL. After topicalization with atomized 4% lidocaine, gentle video laryngoscopy was performed to assess the extent of upper airway soft tissue swelling. The patient was asked to take several breaths to assess movement of the upper airway soft tissues. A 14F AEC was placed through the ETT, aligning it with the ETT markings. Care was taken not to advance it too far into the airway and potentially impinge on the carina.

The AEC was taped to the oxygen face mask. The patient was able to speak with the AEC in place. The patient was observed for 4 hours with the AEC in place, such as can be seen in the photo of a separate patient in Figure 45.3. No signs of upper airway collapse occurred, and the patient showed no signs of respiratory failure. The AEC was removed uneventfully.

Developing an approach to extubating patients in the ED may become an increasingly important part of practice and may help avoid unnecessary continuation of mechanical ventilation and hence reduce associated harm. This may help optimize resource utilization, of particular importance when ICU capacity is under strain and demand outweighs supply. The ability to identify the *at-risk* airway and plan accordingly is imperative. Written criteria for safe extubation are helpful in assisting all health care workers use a common language in extubation planning and assessment. Being comfortable with the adjuncts to extubation, including AECs and transition from extubation to immediate NIV, are a worthwhile skill to have in one’s repertoire.

EVIDENCE

What makes a patient high risk to extubate, and is there evidence to guide safe extubation in emergency patients?

The NAP4 found that nearly one-third of reported major airway complications occurred at extubation.[1] There are no quality ED studies on this topic. Many of our recommendations are extrapolated from the perioperative literature.[2,3] Analysis of the American Society of Anesthesiology Closed Claims Project database showed that 24% of the cases resulting in death or brain death occurred at the time of extubation.[4] Accepted criteria for extubation from the anesthesia literature include resolution of the underlying disease process, appropriate levels of alertness, adequate intrinsic ventilator drive, minimal secretions, and an oxygen saturation >92% with spontaneous breathing.[5-7] One pilot study in trauma patients showed that institution of an extubation checklist decreased the rate of extubation failure.[8] High-risk patients include those with a known difficult airway, obesity, compromised oxygenation, and poor physiology and cardiovascular reserve. Extubation failure is typically the result of either periextubation obstruction and laryngospasm or progressive hypoxic respiratory failure; the latter is most seen in the ICU.[9] Patients who exhibit high-risk features should either remain intubated or undergo extubation with specialty support from anesthesia or otolaryngology.[10]

If a cuff leak is present, what does that mean?

A cuff leak is the difference between the inspiratory tidal volume and the average expiratory tidal volume while the cuff around the ETT is deflated. Lack of an adequate cuff leak (positive test) is variably defined in the literature, but a volume difference <110 to 130 mL is considered a positive result. In a recent meta-analysis of nine studies evaluating the cuff leak test (lack of adequate leak) as a predictor of postextubation airway obstruction, patients with a positive test were four times more likely to have airway obstruction. The pooled sensitivity was 63%, with a specificity of 86%.[11] Additionally, peak inspiratory flows <60 L/min have been associated with an increased incidence of extubation failure.[12]

What is the role of AECs during extubation?

AECs have been shown to increase the first-pass success rate in patients with known or suspected difficult airways requiring reintubation. Mort et al.[13] found an overall success rate of reintubation over an AEC of 92%, with 87% occurring on the first pass. The use of AECs has been shown to be well tolerated by awake patients, if they do not touch the sensitive carina.[13,14] Oxygen insufflation and jet ventilation through AECs can be complicated by barotrauma and should be avoided except in CICO situations. Low oxygen flow rates of 1 to 2 L/min are recommended.[15] Intubation over an AEC should be performed using a video laryngoscope because it results in the highest chance of first-pass success.[13]

Should noninvasive positive pressure ventilation or high-flow nasal oxygen be used after extubation?

There is evidence that extubation to NIV helps reduce the rate of reintubation, ICU mortality, and ICU length of stay.[16] This is most beneficial in patients with COPD, heart failure, chronic respiratory disorders, and those identified at high risk for extubation failure from respiratory failure.[16-18] The length of BiPAP application that has shown to be beneficial at reducing the rate of reintubation has ranged from 24 to 48 hours. In obese patients, extubation to CPAP following general anesthesia or in the recovery room has been shown to decrease the incidence of postoperative respiratory complications.[19] For patients with obstructive sleep apnea, the American Society of Anesthesiology has recommended the continuous use of CPAP or BiPAP in the postoperative period.[20] High-flow nasal cannula applied after extubation may reduce reintubation rates in ICU patients at low risk for extubation failure and is an alternative to NIPPV.[21,22]

What happens to patients who are extubated in the ED?

The data on ED extubations are sparse. In one recent retrospective review of 4 years of observational data from one high-acuity academic medical center, 202 patients were extubated in the ED. Intubations were performed for airway protection (30%), esophagogastroduodenoscopy (28%), intoxication/ingestion (17.3%), respiratory failure (14%), seizure (7%), and other (4%). The median interval from ED arrival to extubation was 9 hours. Nearly one-third were “compassionate” extubations. Of the remaining patients extubated in this ED-ICU (*n* = 142, 70%), zero died, 61% were

admitted to medical-surgical units, 10% were admitted to intensive care, and 28% were able to be discharged home from the ED.[23]

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Index

Note*: Pages followed by f indicate figures; pages followed by t indicate tables; pages followed by b indicate boxes*

A

Abdominal thrust maneuver, 447, 448, 451
Accidental extubation detection, 102
ACEI-induced angioedema. *See* Angiotensin-converting enzyme inhibitor (ACEI)-induced angioedema
Acetylcholine (ACH), 248–256
Acetylcholinesterase (ACHE), 248, 249, 253
Acidosis, difficult airway and, 25–28
Acute infectious causes, difficult airways, 308–311
Acute respiratory distress syndrome (ARDS), 85, 94, 95
Acute respiratory failure, 91
AC ventilation. *See* Assist control (AC) ventilation
Adenoids, 286, 286*t*, 303
Adolescents, airway techniques for, 303–304, 304*f*. *See also* Pediatric airway
  beta-2, 400
Adult difficult airway, risk factors, 306*t*
Advanced Emergency Medical Technician (AEMT), 329
Afrin. *See* Oxymetazoline
Aintree catheter, 146, 149, 150*f*, 457*f*
Air Q device, 145*t*
Airway algorithms, 327
Airway exchange catheter (AEC)
  complications of, 456
  extubation, 457–460, 457*f*, 458*f*, 458*t*, 459*f*, 460
  patient position, 459
  for reintubation, 458*t*, 459*t*
Airway management
  bag-mask ventilation (BMV). *See* Bag-mask ventilation (BMV)
  flexible endoscope intubation. *See* Endoscopic intubation, flexible
  human factors during, 48–57
    cognitive aids, 56
    cognitive bias, 54
    communications, 51–53
    CRM and, 50–51

environmental considerations, 56–57
error, basics of, 50
importance of, 48–50
individual factors, 53–54
mental models, team, 55
safety, 57
Zero Point Survey, 54, 55*f*
laryngeal mask airway. *See* Laryngeal mask airway
timing of, 372–374
Airway obstruction
children, 316
complete, 319–320, 321*f*, 323*f*
partial, 318, 319
Airway ramps, 165
Airway resistance, 311*t*
Albuterol, 400, 401, 403, 404
Algorithms
cardiac arrest airway, 39*f*, 43–44
crash airway, 37, 38*f*
difficult airway, 9, 36–37, 38*f*, 44–46, 269, 408, 411, 414
evidence for, 47
failed airway, 35, 37, 38*f*, 46–47, 408
for foreign body obstruction, 448*f*
as guidelines, 37, 47
main airway algorithm, 9, 38*f*, 39–43
pattern recognition via, 37
for prehospital setting, 331*f*–332*f*
universal emergency airway, 37, 38*f*
utilization of, 37
Alternative airway devices, for pediatric airway, 281
Alveolar decompression, 402
Ambu aScope, 194*f*
Ambu AuraGain, 145*t*
Ambu LMA, 131
American Heart Association (AHA) guidelines, 102, 175
American Society of Anesthesiologists, 243
Amidate. *See* Etomidate
Aminosteroids, 253
Anaphylactic reactions, 311, 316
Anaphylactoid reactions, 311, 316
Anaphylaxis, 311, 312*t*
Anatomical distortion, 5, 405–409, 411
Anectine. *See* Succinylcholine (SCh)
Anesthesia. *See also* Physiologic optimization; Sedation; specific drugs
for asthma, 400
for blind intubation, 201
contraindications for, 268–269
description of, 268

drying imperative for, 269
for endoscopic intubation, flexible, 193, 197
for geriatric patients, 435
glossopharyngeal nerve blocked by, 272, 273*f*
hemodynamic stability influenced by, 380
indications for, 268–269
Jackson forceps used in, 273, 273*f*
local, 269–274
for obese patients, 440
for pediatric airway, 287, 288*t*
during pregnancy, 412, 414
for reactive airways disease, 400
superior laryngeal nerve blocked by, 273
techniques for
hypopharynx, 268, 272–273
larynx, 273–274
mouth, 268, 271–272
nose, 201, 270
oropharynx, 272–273, 273*f*
trachea, 274
vasoconstriction with, 270
Angioedema, 311, 408
Angiotensin-converting enzyme inhibitor (ACEI)-induced angioedema, 409
Anterior larynx, 13
Anticholinergics, inhaled, 400, 403
Anticipated clinical course, 312*t*, 315
timing of intervention, 312*t*
Antihypertensive agents, 411
Antimuscarinic agents, 269
Apnea, 91, 231, 374, 439*b*, 440
Apneic oxygenation, 80, 289
ARDS. *See* Acute respiratory distress syndrome
Arterial blood gas values, 6–7
Arterial oxygen saturation, pulse oximeters, 96
Assist control (AC) ventilation, 91
Asthma
anesthesia for, 400
challenges of, 401
children, 318
mechanical ventilation and, 94
status asthmaticus and, 4, 401
treatment of, 400, 401–403
Ativan. *See* Lorazepam
Atracurium, 253
“At-risk” airway, 454, 460
Atropine, 253
asthma and, 400
bradycardia prevented by, 252, 294

children and, 252, 288*t*, 294
COPD treated with, 400
ketamine used with, 243
succinylcholine used with, 252
Atrovent. *See* Ipratropium bromide
Auto-positive end-expiratory pressure (auto-PEEP), 92*f*, 93, 93*f*, 94
Awake cricothyrotomy, 276
Awake intubation. *See also* Blind nasotracheal intubation
anesthesia for, 268–277, 409
for obstructed airways, 409
sedation for, 269, 274–275, 409
successful attempts and, 260
Awake laryngoscopy, 63, 193
in difficult airway algorithm, 45–46, 268
roles of, 268

B

Backward, Upward, Rightward Pressure (BURP) maneuver, 169, 175, 299
Bag-mask ventilation (BMV), 45, 64, 71, 109–121, 238, 239, 282
after NMBA usage, 37
airway approach to, 433
airway obstruction and, 406
cadence for, 298
catheters for, 302*t*
description of, 109
devices, 109, 110*f*
difficult, 9, 15–16, 438
predicting, 118
techniques, 120
troubleshooting, 118
difficult airway, 308, 321, 432
EMS airway management and, 327
experience and, 119
face mask ventilation techniques, emergency setting and, 110–117
adequacy assessment, 117
aspiration risk, 117
head and neck maneuvers, 113–114, 114*f*
neuromuscular blockade, 116
optimizing face mask seal, 110, 111*f*
oral and nasal pharyngeal airways, 114–116
Sellick maneuver, 117
single-handed mask grip, 112
stomach inflation, 117
thenar grip, 111–113, 112*f*
two-handed mask grip, 113
ventilation parameters, 116–117
foreign body aspiration and, 446

gastric insufflation during, 297, 300
impossible, 117–118
indications for, 39*f*, 42–44
leaks in, 300–301
mask position and holding
two-handed mask hold, 433, 441
mask seal in, 297, 300–301, 407, 433, 441
non-rebreather mask, 289–290, 293*b*
for obese patients, 438, 441, 443
optimizing, checklist for, 118*t*
oxygenation, 408
for pediatric airway, 282, 285*f*, 287, 287*b*, 288*t*, 289, 291*t*, 297–301, 298*f*, 300, 302*f*, 302*t*, 304*b*
pregnancy and, 410–415
prehospital airway management and, 337
Sellick maneuver, 297
soft tissue obstructions, 406
storage of, 291
training and, 119
Bag-valve mask (BVM), 76–79
fraction of inspired oxygen and, 73*t*
Bambuterol, 252
Barbiturates, 240
ultra-short-acting, 240
Barotrauma, 300, 303, 402
Basic Life Support (BLS) providers, 329, 354
β-blockers, 431
Beck Airway Flow Monitor (BAAM), 203
Benzodiazepines, 64, 242, 377
adverse effects of, 244
clinical pharmacology of, 244
contraindications for, 244
dosage of, 244
hemodynamic stability influenced by, 244
histamine and, 244
indications for, 244
as induction agent, 246
ketamine used with, 243
for rapid sequence intubation (RSI), 246
reactive airways disease and, 402
as sedative induction agent, 244
Berman breakaway airway, 195, 195*f*
Beta-2 adrenergic agonists, 400, 402
eleven11-β-hydroxylase, 242
Bilevel positive airway pressure (BLPAP), 230, 400, 460
Bimanual laryngoscopy, 169, 169*f*
BiPAP. *See* Biphasic positive airway pressure
Biphasic positive airway pressure (BiPAP), 86, 231*b*
Bite-blocks. *See* Oral airways

Blind intubation
anesthesia for, 201
attempts at, 201, 203
description of, 200
DTI as, 204
in semielective exchange for ETT, 145
tongue during, 204
Blind nasotracheal intubation (BNTI)
contraindications for, 200, 286, 293*b*
description of, 204
ETTs in, 201, 204
head positioning in, 202, 204
indications for, 200
pediatric airway and, 286, 287*f*, 291*t*, 293*b*, 303–304
in prehospital setting, 205
preoxygenation in, 201
success rates of, 204
techniques for, 201–204
troubleshooting, 204
BLPAP. *See* Bilevel positive airway pressure
BNTI. *See* Blind nasotracheal intubation
Bougie, 146*f*, 161, 167, 170*f*–172*f*, 170*f*, 175, 205. *See also* Endotracheal tube introducer
Bradycardia, 376
atropine preventing, 173, 252, 294
in children, 252
succinylcholine influencing, 252
Bradypnea, 374
Bradypneic (classic) hypoventilation, 103, 103*f*
Breath stacking, 92*f*, 94
Brethine. *See* Terbutaline
Brevibloc. *See* Esmolol
Brevital. *See* Methohexital
Bronch adapter, 148
Bronchospasm, 104, 400, 402, 456*t*
Broselow-Luten system, 282, 283*t*–284*t*, 287, 294, 311, 320
Burns, 311–312
difficult pediatric airway, 311–312
injuries, hyperkalemia and, 251
BURP maneuver. *See* Backward, Upward, Rightward Pressure (BURP) maneuver
Butyrophenone, 275

C

Calcium channel blockers, 431
Calcium gluconate, 252
Can’t intubate, can’t oxygenate (CICO), 458
cricothyrotomy required by, 47, 301, 433
failed airway

defined by, 34, 46
Capnography, 7, 175, 202, 202*f*, 203, 203*f*, 205, 228, 232, 458*t*
face masks, 101
interpretation, 101*f*–102*f*, 101*t*
and quantitative capnometry clinical utility
during cardiopulmonary resuscitation, 102–103, 103*f*
ETT placement confirmation and accidental extubation detection, 102, 102*f*
mechanically ventilated patients surveillance and monitoring, 104
respiratory distress patient assessment and monitoring, 104
ventilation monitoring during procedural sedation, 103–104, 103*f*–104*f*
types, 100
Capnometers, 232
Capnometry and capnography, quantitative, 102–104
Carboxyhemoglobin (CO-Hgb), 98
Cardiac arrest, 173
Cardiac arrest airway algorithm, 39*f*, 40
Cardiac dysfunction, 375
Cardiac tamponade, 378*b*
Cardiogenic pulmonary edema, 375
Cardiopulmonary resuscitation (CPR)
capnography during, 102–103, 103*f*
Cardiorespiratory emergencies, 417–420
approaches, 419
challenges, 417
induction agent, choice of, 418
intubation sequence, recommended, 419
mechanical ventilation, initiating, 419
paralytic agent, choice of, 418–419
reflex sympathetic response to laryngoscopy and, 417–418
tips for, 420
Cardiorespiratory reserve, decreasing of, 431–432
Cardiovascular shock, 373
Catecholamines
ketamine releasing, 242
reactive airways disease and, 401
Catheters
for BMV, 302*t*
pediatric, 283*t*, 302*t*
transtracheal, 302*t*
Central arterial oxygenation, 375
Cephalad, 169, 169*f*
Cerebral metabolic rate for oxygen (CMRO2), 240, 243
Chest thrusts, 448
Chest X-rays, endotracheal tube introducer (ETT) and, 174
Children. *See also* Pediatric airway
asthma, 318
atropine and, 252, 288*t*, 294
choking, 318, 323

consciousness, 319–319
coughing, 318, 322
desaturation in, 228, 229*f*, 237, 286, 287*b*, 293*b*, 295, 297
failed airways incidence in, 316–317
Heimlich maneuver, 318, 322, 323
Mallampati scoring system in, 317
wheezing, 318
Choking, in children, 318, 323
Chronic obstructive pulmonary disease (COPD), 104
challenges of, 400–401
in geriatric patients, 433, 434
treatment of, 400–401, 403
CICO. *See* Can't intubate, can't oxygenate
Cisatracurium, 253
C-MAC video laryngoscope, 174
CMRO2. *See* Cerebral metabolic rate for oxygen
Coagulopathy, 200
Cocaine, 270
Cognitive aids, 56
Cognitive bias, 54
CO-Hgb. *See* Carboxyhemoglobin
Cola complication, 175
Colorimetric CO2 detectors, 100, 105
Comas, GCS for, 7
Combitube (ETC), 126, 145*t*, 315*t*
pediatric airway and, 293*b*
CO2 monitoring, 100–101
Compensated shock, 374, 376
Complete airway obstruction, 319–320, 321*f*, 323*f*
Computed tomography (CT) scans, 5
Congenital abnormalities, in difficult pediatric airways, 316
Consciousness, in children, 319–320
Continuous positive airway pressure (CPAP), 86, 231*b*, 328, 431, 433, 457, 461
Continuous waveform capnography, 105
Cook catheters, 302*t*
Cookgas Air-Q, 131
Cookgas ILA device, 145*t*
Co-oximeters, 98
COPD. *See* Chronic obstructive pulmonary disease
Cormack-Lehane Laryngoscopic Grading System, 162*f*, 173
Cough, 456*t*
children, 318, 322
foreign body clearing, 322
COVID-19 pandemic, 421
CPAP. *See* Continuous positive airway pressure
CPP. *See* Cerebral perfusion pressure
CPR. *See* Cardiopulmonary resuscitation
Crash airway algorithm, 37, 38*f*

Crash situation
EGDs, 315*t*
ET intubation, 315*t*
expectant management patients, 315*t*
surgical airway, 315*t*
Cricoid cartilage, 64, 286*t*, 287*f*, 289*f*
Cricoid pressure. *See* Sellick maneuver
Cricothyroid membrane (CTM), 67, 207, 274, 286, 286*t*, 287*f*, 289*f*, 291
Cricothyrotomy, 356
for airway obstruction, 405–408
awake, 276
CICO requiring, 46, 301, 433
contraindications for, 293*b*
difficult, 16–17, 41, 46, 207*b*, 438
for foreign body aspiration, 450
indications for, 41*f*
needle, 291, 291*t*, 293*b*, 304*b*, 322
for obese patients, 438, 442, 444
in oxygenation, 408
for pediatric airway, 285*f*, 286, 291, 291*t*, 293*b*, 301–303, 303, 304*b*
Seldinger technique for, 304*b*
SMART mnemonic for, 40
trays, contents in, 208*b*
Crush injuries, 255
CT scans. *See* Computed tomography (CT) scans
Cuff leak test, 454–455, 455*b*, 461

D

Dantrolene (Dantrium), 252
Delayed sequence intubation (DSI), 79–80, 236–237, 238, 362, 403
Delirium, 460
Denervation, 251, 255
Denitrogenation, difficult airway and, 23
Depolarizing NMBAs, 253
Desaturation
in children, 228, 229*f*, 237, 286, 287*b*, 293*b*, 295, 297
in geriatric patients, 435
hemodynamic stability and, 401
in obese patients, 228, 229*f*, 237, 440, 443
in pregnant women, 228, 229*f*, 410, 411
with reactive airways disease, 401
time to, 229, 229*f*
Dexmedetomidine (Precedex), 240, 246, 275, 276, 459, 460
Dexterity, 199
Diabetes, 439*b*, 440
Diabetic ketoacidosis, 373
Diaphoresis, 400

Difficult airway, 9–20, 40*f*, 47, 268, 314*f*. *See also* Difficult pediatric airway
algorithm for, 9, 36–37, 38*f*, 40*f*, 354–356, 408, 440
awake laryngoscopy in, 45–46, 268
critical actions for, 44, 45–46
key questions for, 44–45
for pregnancy, 411
RSI in, 45–46
anatomically, identification
description, 9
RODS and, 16
ROMAN and, 15–16
SMART and, 16–17
BMV and, 9, 34
cricothyrotomies and, 40, 46
EGDs and, 40
in EMS airway management, 352–357
identification of, 40–41, 44, 47
increased incidence of, 432–433
intubation of, 44–45, 199
LEMON airway mnemonic for, 40–41, 411, 440
physiologically, identification, 21–30
CRASH and, 22*f*
definition, 21
management of, 23–28
prediction of, 21–22
preparation for, 22–23
RODS airway mnemonic for, 40, 411
ROMAN airway mnemonic for, 40–41, 411
SMART airway mnemonic for, 40
Difficult Airway Society (DAS), 453
risk stratification, 453–454, 453*t*
Difficult laryngoscopy, 10–15
Difficult pediatric airway
abnormal facial features, 306
acute infectious causes
children, 308–311
endotracheal tube (ETT), 308, 311
epiglottitis, 308
Ludwig angina, 311
respiratory distress, 308
retropharyngeal abscess, 311
anaphylactic reactions, 311, 316
anaphylactoid reactions, 311, 316
anaphylaxis, 312*t*
anticipated clinical course, 312*t*, 315
in children, 306–317
congenital anomalies
invasive airway management, 312–314

laryngoscope blade, 313*f*
LEMON assessment, 312
micrognathic mandible, 312
techniques, 312–314
early intervention group, 312*t*
expectant intervention group, 312*t*
infectious and noninfectious causes, 316
intervention, 316
noninfectious processes
anaphylaxis, 311
angioedema, 311
burns, 311–312
foreign body aspiration, 311
normal and difficult airways, management, 307*t*
pediatric patients, 306
pediatric *versus* adult risk factors, 306*t*
signs and symptoms, 316
therapeutic options, 315*t*
Digital tracheal intubation (DTI)
as blind intubation, 204
contraindications for, 204
indications for, 204
success rates of, 205
techniques for, 205
Diprivan. *See* Propofol
Direct airway placement devices, 220
Direct laryngoscopy (DL), 37, 40, 300, 449*f*
anatomy, 161, 162*f*
definition, 159
difficult, troubleshooting
bimanual laryngoscopy, 169, 169*f*
endotracheal tube introducer, 170–171, 170*f*–172*f*
laryngoscopy and intubation, failed, 172–173
paralysis, 169
tracheal intubation confirmation, 147–150
handling and operator posture, 163
Macintosh blades, 159, 160*f*
Miller blades, 159, 160*f*, 161*f*
patient positioning, 163–165, 164*f*, 174–175
pediatric difficult airway, 311, 316
preintubation assessment and equipment choice, 163
preparation and assistance of, 163
routine intubation, 144–145
standard technique, 160*f*, 165–166, 165*f*, 166*f*
straight blade, blind insertion, 168
thyroid cartilage, 175
tracheal intubation, 166
video laryngoscopy *vs*., 182

working around EGD, 145
Distortion, of upper airway, 5, 405–406, 411
Disuse atrophy, 435
Down-then-up maneuver, 450
DTI. *See* Digital tracheal intubation
D-tubocurarine, 253
Dynamic hyperinflation, 377
Dyshemoglobinemia, pulse oximetry, 97*t*
Dysrhythmia, 250

E

Early intervention group, 312*t*
EasyTube. *See* Rusch EasyTube
Echocardiography, 373
Eclampsia, 412
Edema
angioedema as, 406, 408
mucosal, 411
upper airway obstructed by, 413
Edrophonium, 248
EGDs. *See* Extraglottic devices
Elevated intracranial pressure
neurocritical patients, 394
Emergency airway algorithms, 36. *See also* Algorithms
Emergency airway management, 311
Emergency department (ED), 5
endoscopic intubation, 199
instrument selection for, 193
observation unit, 409
Emergency Medical Responder (EMR), 329
Emergency medical services (EMS) airway management, 141
airway approach in, 331*f*–332*f*
applying difficult airway algorithm
for MFAM practitioners, 354–356, 355*f*
for non-MFAM provider, 356
approach to, 327–328
cardiopulmonary optimization for, 371–380
clinical challenge, 327
controversies in, 359–365
airway strategies for OOHCA, 360
delayed sequence intubation, 362
front of neck access, 359–360
medication-facilitated airway management, 360–362, 361*f*
scene times, 362–363
difficult airway in, 352–357
prediction in prehospital setting, 352–353
introduction to, 327–332

invasive pediatric airways, 363
mechanisms for maintenance of competency, 330
number of providers, 363
prehospital challenge, 352
prehospital conundrum, 353
prehospital NIPPV, 364
rapid or critical oxygen desaturation, 357
rapid sequence airway, 364
tips for, 358
training and practice, 328–330
in unstable patients, 371–380
Emergency Medical Technician (EMT), 329
Emergency surgical airways, 206–221
anatomy and landmarks, 207–208
complications, 213
contraindications, 207
description of, 206
direct airway placement devices, 220
general approach of, 206
indications, 207
Seldinger technique, 213–219
techniques, 208–213
Endoscopic exchange, in semielective exchange for ETT, 147–150, 150*f*, 151*f*
Endoscopic intubation, flexible
anesthesia for, 193, 197
complications, 198–199
components of, 196, 197*f*
contraindications, 193
description, 192
indications and contraindications, 192–193
psychomotor skills for, 193, 199
technique, 196–198
dexterity, 193
instrument care, 195–196, 195*f*–196*f*, 197*f*
overview, 193
preparation, 193
psychomotor skills, 193, 199
scope selection, 193–194
Endotracheal intubation (ETI), 328
BURP maneuver in, 299
for pediatric airway, 291, 291*t*, 298*f*
prehospital airway management and, 338–341
Endotracheal tube (ETT), 442
AEC and, 457, 459, 460
airway management, 308, 311
in BNTI, 204
confirmation method, 175
cuffed, 41*f*, 46, 205

difficult pediatric airway, 308, 311
endoscopic intubation, 196–198
foreign body aspiration, 322
insertion of, 288
laryngoscopy, 312
larynx, 314
for mechanical ventilation, 90
for pediatric airway, 283*t*, 288–289, 288*t*, 289*f*, 300, 302*f*, 303, 304*f*
pediatric diagnosis, 311
placement confirmation of, 102, 232, 235*t*, 293
positioning of, 66, 231
preparation of, 228
retropharyngeal abscess, 311
securing devices for, 289, 290*f*
selection of, 66, 201, 228
semielective exchange for, 144–150
softening of, 61
uncuffed, 295
Endotracheal tube introducer (ETI), 170*f*–172*f*
counterclockwise rotation of, 172*f*
in tracheal intubation, 161
Endotrol tube, 61, 202*f*, 203, 204
End-tidal carbon dioxide (ETCO2), 173, 175
detection, 232, 291, 293. *See also* Capnography
monitoring, 100
basics, 100
capnography interpretation, 101
capnometry and capnography, quantitative, 102–104
colorimetric CO2 detectors, 100
guidelines, in emergency settings, 105
quantitative CO2 monitors, 100–101, 100*f*
Enflurane, 240
EPAP. *See* Expiratory positive airway pressure
Epiglottis, 198, 286, 287*f*, 301, 304*f*
obstruction by, 301
visualization, 286, 407
Epiglottitis, 406*b*, 407
agitation of children, 308
Epinephrine, 231*b*, 269
asthma treated with, 400, 401
for geriatric patients, 434
for pediatric airway, 282
vasoconstriction caused by, 282
Epistaxis, 61, 198, 201–202
Esmolol (Brevibloc), 252
Esophageal intubation, 102, 102*f*
unrecognized, 236
Esophageal tracheal Combitube. *See* Combitube

ETC. *See* Combitube
ETCO2. *See* End-tidal carbon dioxide
ETI. *See* Endotracheal intubation
Etomidate (Amidate), 240, 245
  adverse effects of, 242
  clinical pharmacology of, 241–242
  contraindications for, 241–242
  dosage of, 242
  hemodynamic stability influenced by, 241–242, 245, 376, 434
    ICP influenced by, 241
  indications for, 241–242
  as induction agent, 240, 241–242, 245
  for obese patients, 443*t*
  for pediatric airway, 288*t*
  reactive airways disease and, 401
  for RSI, 245
  septic patients, 245
Expectant intervention group, 312*t*
Expiratory stridor, 6
External laryngeal manipulation (ELM), 356
Extraglottic devices (EGDs), 124–137, 329, 352, 354. *See also* Intubating laryngeal mask airway; Retroglottic devices; Supraglottic devices
  complications, 135
  description of, 124–125
  difficult airways and, 16, 40, 312
  laryngeal mask company devices. *See* Laryngeal mask airway
  limitations, 135
  for obese patients, 440
  oxygenation, 407
  patient management, 141–153
    algorithm, 142*f*
    assessment, 142
    optimization, 144
  permissible to pronouncing patient in cardiac arrest dead with, 153
  pregnancy and, 411
  retroglottic devices, 125–128
  RODS mnemonic for, 40
  semielective exchange
    blind exchange, 145–146
    consideration of, 144
    endoscopic exchange, 147–150, 150*f*, 151*f*
    performance of, 144–150
    removal after intubation, 150–152
    removal with routine intubation via direct/video laryngoscopy, 144–145
    surgical airway, 152
    techniques, 145*t*
    working around device and performing intubation with direct/video laryngoscopy, 145
  supraglottic devices, 128–132

techniques for usage of, 132–135
troubleshooting, 143–144
usage of, 36, 40*f*, 43, 44–45, 46
contraindications for, 125
in emergency airway management, indications for, 125
Extrathoracic trachea, 282, 285*f*
Extubation
additional testing, 454–455, 455*b*
adjuncts to, 457–460
airway exchange catheter (AEC), 457–460, 457*f*, 458*f*, 458*t*, 459*f*, 459*t*
clinical challenge, 452
complications, 456, 456*b*, 456*t*
criteria, 453, 453*t*
of emergency patient, 452–462
general, 453*t*, 455–456, 456*t*
high risk of, 457
noninvasive ventilation (NIV), 460
planning for, 452
process of, 455–457
risk stratification, 453–454, 453*t*
sedation during, 460
Eye injuries, 255

F

Face masks
simple, 73*t*, 75
Failed airway, 41*f*, 46–47
algorithm, 37, 38*f*, 41*f*, 46–47, 408
critical actions for, 46–47
key questions for, 46–47
definition of, 42, 46–47
LMAs in, 304–305
Failed intubation, 172–173, 174
Failed laryngoscopy, 172–173, 173*t*
Fasciculation, 250, 253
FBA. *See* Foreign body aspiration
Fentanyl (Sublimaze), 231
for preintubation optimization, 234*f*
reactive airways disease and, 402
First attempt intubation success
airway practitioners, importance of, 265
algorithm and, 264–265
checklists, 261–262, 266
equipment, usage of, 263–264
importance of, 258, 266
keys to optimizing, 258
neuromuscular blockade, importance of, 259–261

awake intubation, usage of, 260
rapid sequence intubation, appropriate usage of, 259–260
ownership and, 265–266
personnel, usage of, 263–264
preintubation checklist, 261–262
preoxygenation, critical and, 262–263
standardized approach, usage of, 259
techniques, usage of, 263–264
Flexible endoscope (FE), 41*f*, 47, 205, 407
intubation. *See* Endoscopic intubation, flexible
Flush rate, 411
Fogging, 174
FO laryngoscopy. *See* Fiber-optic laryngoscopy
Forced to act scenario, 37, 40*f*, 44, 46, 354
Forceps
Jackson, 273, 273*f*
Magill, 303, 448
Foreign body
intrathoracic pressure, 319
during laryngoscopy, 322
reflexive cough, 322
visualization, 322
Foreign body aspiration (FBA)
airway obstruction caused by, 406*b*, 446–451, 448*f*
algorithm for, 448*f*
back blows for, 451
BMV and, 448
challenges of, 446
complete airway obstruction, 319–320, 321*f*, 323*f*
cricothyrotomy for, 450
difficult pediatric airway, 311
evidence, 451
Heimlich maneuver for, 447, 448*f*
partial airway obstruction, 318, 319
postintubation management for, 450
stepwise approach, 322*f*
technique for
complete obstruction, 448–450, 448*f*
incomplete obstruction, 447
tips for, 450
ventilation and, 448–449, 448*f*
Fractional concentration of inspired oxygen (FiO2), 90
mechanical ventilation, 90
synchronized intermittent mandatory ventilation (SIMV), 91
Fraction of inspired oxygen (FiO2), 72
low/high delivery systems, 73*t*
Frank hypotension, 376
FRC. *See* Functional residual capacity

Functional residual capacity (FRC), 72, 410, 438, 439*b*
difficult airway and, 23

G

GABA receptors, 241, 243
Gag reflex, 7
Ganglionic blockade, 253
Gas exchange, 4
Gastric contents, aspiration of, 4, 236
Gastric insufflation, 194, 297, 300
Gastrointestinal changes
in obese patients, 439*b*
during pregnancy, 412
GCS. *See* Glasgow Coma Scale
Geriatric patients
airway approach to, 433–434
challenges of
cardiorespiratory reserve, decreasing of, 431–432
difficult airway, increased incidence of, 431
ethical considerations, 433
difficult intubation, 435
hyperkalemia in, 251–252
paralysis with induction, 434
physiologic optimization, 433–434
postintubation management, 434
tips for, 435
GFR. *See* Glomerular filtration rate
Glasgow Coma Scale (GCS), 7
GlideScope video laryngoscope (GVL), 291, 444
Glomerular filtration rate (GFR), 439*b*, 440
Glossopharyngeal nerve, 64, 272, 273*f*
Glottis
in pediatric airway, 286, 286*t*, 287*f*
visualization of, 45, 66, 161, 167–168, 169–170, 172*f*, 198, 202, 268–269, 299, 459
Glucose, 252
Glycopyrrolate (Robinul), 193, 197, 243, 253, 269
Gram-positive cocci, 308
GVL. *See* GlideScope video laryngoscope

H

Haloperidol, 234*f*, 275
Halothane, 240
Heimlich maneuver, 447, 448*f*
children, 319, 322, 323
Heliox, 404
Hematoma, 407

Hemodynamic alterations, 456*t*
Hemodynamic optimization, for emergency airway management, 372*b*, 375–376, 378*b*–379*b*, 380
Hemodynamic stability
  anesthesia influencing, 241–246, 434
  difficult airway and, 25–28
  during pregnancy, 412
  with reactive airways disease, 400
Hemoglobin saturation (Sao2), 96, 98–99
Hemopneumothorax, 5
Hemorrhagic shock, 375
Hemothorax, 6
High-concentration oxygen *versus* supplemental oxygen, 73–74
High-flow nasal cannula (HFNC), 82, 230, 237, 372, 375, 380
High-flow nasal oxygen, 74–75, 85–88
High-pressure (jet) ventilation, 457, 457*f*, 461
Histamine, 243, 253, 402
Hudson DCI (simple face mask), 75
Human factors, airway management and, 48–57
  cognitive aids, 56
  cognitive bias, 54
  communications, 51–53
  CRM and, 50–51
  environmental considerations, 56–57
  error, basics of, 50
  importance of, 48–50
  individual factors, 53–54
  mental models, team, 55
  safety, 57
  Zero Point Survey, 54, 55*f*
Hydantoin, 252
Hydromorphone (Dilaudid), 233, 234*f*
Hyperangulated video laryngoscopy, 185–188
Hypercapnia, 90, 374, 402
Hypercarbia, 304
Hyperkalemia
  in geriatric patients, 251–252, 435
  increased risk of
    from burn injuries, 251
    from crush injuries, 251, 255
    from denervation, 251, 255
    from myopathies, 251
    from pre-existing hyperkalemia, 252, 255
    from prolonged immobility, 255
    from severe infections, 251
  malignant hyperthermia and, 252–253
  receptor upregulation causing, 250–252
  rhabdomyolysis causing, 250–252
  succinylcholine inducing, 250–252, 255, 287

Hyperthermia, 252–253
Hyperventilation, 377
Hypopharynx
  anesthesia techniques for, 268, 272–273
Hypopneic hypoventilation, 103, 104*f*
Hypotension, 5, 231, 232, 232*t*, 236, 240, 243, 245, 252, 374
  in geriatric patients, 434, 435
  with reactive airways disease, 402
Hypotensive shock, 376
Hypoventilation, 91, 374, 456*t*
Hypovolemia, 376, 434
Hypovolemic shock, 378*b*
Hypoxemia, 45, 71, 142, 232, 372, 439*b*, 440, 444
Hypoxemic respiratory failure, 379*b*
Hypoxia, 287*b*, 294, 304, 433

I

ICP. *See* Intracranial pressure
Ideal body weight (IBW) dosing, 442
I/E ratio. *See* Inspiratory to expiratory (I/E) ratio
IFR. *See* Inspiratory flow rate
I-Gel device, 145*t*
ILMA. *See* Intubating laryngeal mask airway
Imidazole, 241
Impending circulatory collapse, 232
Induction agents
  benzodiazepines as, 244, 245
  cardiopulmonary optimization for emergency airway management, 376, 378*b*–379*b*
  description of, 240
  etomidate as, 241–242, 245, 434
  ketamine as, 242–243, 245, 434
  propofol as, 243–244, 245, 434
  RSI, 245–246
  ultra-short-acting barbiturates as, 240
Infants, pediatric basic life support techniques. *See* Pediatric airway
Infectious patient, highly, 421–423
  aerosolization, limiting, 422–423
  challenges, 421
  exposure, limiting, 422
  noninvasive oxygenation strategies and risk, 423
  tips for, 423
Inferior turbinate, 61*f*, 202
Infraglottic devices (IGDs). *See* Retroglottic devices
Inhaled anticholinergics, 403
Innervation
  of larynx, 64–67
  of pharynx, 64

Inspiratory flow rate (IFR), 90
Inspiratory to expiratory (I/E) ratio, 92
Insufflation, 194
Insulin, 252
Intensive care units (ICUs), 141
Interfacility transfer, 7
Intersurgical i-gel, 132
Intracranial pressure (ICP)
  anesthesia and, 241
  fasciculations occurring with, 250
Intragastric pressure, 250
Intraocular pressure, 250, 255
Intrathoracic pressure, 90, 293, 320, 373, 376–377, 401
Intrathoracic trachea, 285*f*
Intravenous dye, pulse oximetry, 97*t*
Intubating laryngeal mask airway (ILMA), 47, 441
Intubation. *See also* Algorithms; Awake intubation; Blind intubation; Nasotracheal intubation; Orotracheal intubation; Rapid sequence intubation
  See also Algorithms; Awake intubation; Blind intubation; Nasotracheal intubation; Orotracheal intubation; Rapid sequence intubation
    endoscopic. *See* Endoscopic intubation, flexible
  anatomical distortion and, 5
  approach to patient, 5–7
  arterial blood gas values and, 6–7
  attempts at, 40*f*, 42–43, 46
  difficult, 192
  of difficult airways, 44–45, 199
  endotracheal. *See* Endotracheal intubation
  evidence, 7
  highly infectious patient, 421–423
    aerosolization, limiting, 422–423
    challenges, 421
    exposure, limiting, 422
    noninvasive oxygenation strategies and risk, 423
    tips for, 423
  indications for, 3–5
    airway patency or protection failure, 4
    clinical course prediction, 4–5
    oxygenation failure, 4
    ventilation failure, 4
  before interfacility transfer, 7
  LEMON mnemonic for, 41
  reversible conditions and, 4
Intubation Orotracheal intubation; Rapid sequence intubation
  anatomical distortion and, 405–409
  attempts at, 435
  cardiovascular risk, in elderly patients, 435–436
  difficult, 268, 435, 438

LEMON mnemonic for, 411, 440
success rates of, 255
unrecognized esophageal, 236
Ipratropium bromide, 400, 403, 404
Isoflurane, 240

J

Jackson forceps, 273*f*
Jaw thrust maneuver, 170, 175, 329*f*, 356
Jet ventilation. *See also* Percutaneous transtracheal ventilation
high-pressure, 457, 457*f*, 461

K

Ketalar. *See* Ketamine
Ketamine (Ketalar), 242–243
adverse effects of, 244
atropine used with, 243
in awake intubation sedation, 243, 275
benzodiazepines used with, 243
brain-injured patient, 245
catecholamines released by, 243
clinical pharmacology of, 242
contraindications for, 242–243
dosage of, 243
hemodynamic stability influenced by, 243, 376
histamine and, 401
ICP influenced by, 243
indications for, 242–243
as induction agent, 240, 242–243, 245, 434
for pediatric airway, 288*t*
propofol used with, 275
reactive airways disease and, 400, 401, 404
for RSI, 245
sedation, 319
sympathetic stimulation influenced by, 242
Ketofol, for RSI, 245
Kiesselbach’s plexus, 60
King iLT-D device, 145*t*
King LT airway, 145*t*, 407
King LTS-D airway
pediatric airway and, 303

L

Larson’s maneuver, 457*t*
Laryngeal crepitus, 6
Laryngeal mask airway (LMA), 128–130, 407

Ambu LMA, 131
complications, 301, 305
contraindications, 301
Cookgas Air-Q, 131
devices
Ambu AuraGain, 145*t*
Classic, 414
Fastrach, 145*t*
ProSeal, 414
Supreme, 145*t*
Unique, 145*t*
difficult pediatric airway, 315*t*
in failed airways, 304–315
ILMA as, 47, 441
Intersurgical i-gel, 132
for pediatric airway, 284*t*, 291*t*, 301, 304
success rates of, 304
technique, 301, 304–305
usage of, 46
Laryngeal Tube airway. *See* King LT airway
Laryngeal tube airway, 127
Laryngoscopic blade, 175
Laryngoscopy. *See also* Direct laryngoscopy; Video laryngoscopy
attempts at, 42–43, 413
awake, 45–46, 63, 193, 268
bimanual, 169, 169*f*
blades, 175, 288
Macintosh blades. *See* Macintosh blades
Miller blades. *See* Miller blades
in pediatric airway, 283*t*, 286*t*, 288, 288*t*, 293*b*
difficult, 10–15, 441
direct, 45, 300
orotracheal intubation and, 270
tongue placement during, 63
video, 228
video *versus* direct, 444
Laryngospasm, 243, 407, 454, 457*t*
management, 456*b*
risk factors, 456*b*
Larynx, 6, 202
anatomy of, 61*f*, 64–67, 65*f*–66*f*, 304*f*
anesthesia techniques for, 273–274
difficult pediatric airway, 312
innervation of, 64–67
reflex sympathetic activation in, 64
trauma to, 66
visualization of, 205, 286*t*, 407
Leak test for BMV, 300–301

LEMON mnemonics, 40–41, 192, 352, 354, 411, 440
  assessment
    children, 306, 307*t*
    micrognathic mandible, 312
    upper airway obstruction, 316
Lidocaine (Xylocaine), 457
  in awake intubation anesthesia, 269–274
  in blind intubation anesthesia, 201
  in endoscopic intubation, flexible, 197, 198
  propofol used with, 244
Light-emitting diodes (LEDs), 96
Lignocaine. *See* Lidocaine
Little's area. *See* Kiesselbach's plexus
LMA. *See* Laryngeal mask airway
Look as you go approach, 166
Lorazepam (Ativan), 377
Lower airway obstruction, expiratory stridor, 6
Low-flow nasal oxygen, 74–75
Low-risk extubation, 456
Lung disease. *See* Ventilator-induced lung injury

M

Macintosh blades, 159, 160*f*, 163, 165*f*
MAD. *See* Mucosal atomization device
Magill forceps, 303, 448
Magnesium, 403
Main airway algorithm, key questions for, 40–43
Main emergency airway algorithm, 38*f*, 39
  critical actions for, 41
Malignant hyperthermia (MH), 252
Mallampati scoring system, 317, 435, 440
Malperfusion, 374
MAP. *See* Mean arterial pressure
Mask seal, in BMV. *See* Bag-mask ventilation
Massively soiled airway (MSA), 425–429
  approaches, 425
  challenges, 425
  regurgitation
    managing, 426
    prevention of, 425–426
  SALAD Technique, 426–428
Mechanical ventilation, 228, 234*f*, 292*t*, 373
  ARDS and, 95
  asthma and, 94
  cardiorespiratory emergencies and, 419
  complications of, 403
  emergency airway management and, 376–377

ETT for, 94*b*
initiation of, 60, 90
minute volume of, 93
modes of, 90–91
neurocritical patients, 396–397
noninvasive
modes of, 86
techniques, 93
for pediatric airway, 291–292, 292*t*
during pregnancy, 410
reactive airways disease and, 90, 402
recommended obstructive lung physiology, 94*b*
terminology of, 89–90
tidal volume delivery of
pressure-control, 92–93, 92*f*–93*f*
pressure cycled, 292*t*, 402
volume-control, 92*f*
volume cycled, 91–93, 292*t*, 402
tips for, 94
ventilator settings, 93*b*
Medication-facilitated airway management (MFAM), 200, 328
applying difficult airway algorithm, 354–356
EMS airway management and, 360–362, 361*f*
prehospital airway management and, 343–347
Mental models, team, 55
Met-Hb. *See* Methemoglobin
Methemoglobin (Met-Hgb), 98
Methohexital (Brevital), 240
Metoclopramide, 252
MH. *See* Malignant hyperthermia
Micrognathia, 314*f*, 317
Midazolam (Versed), 64, 233, 234*f*, 240, 244, 275, 377
dosage of, 244
for pediatric airway, 288*t*
reactive airways disease and, 401
Middle turbinate, 61*f*
Miller blades, 159, 160*f*, 161*f*, 166*f*
Mivacron. *See* Mivacurium
Mivacurium, 253
Morbidly obese patients. *See* Obese patients
Morphine, 233, 234*f*
Motion artifact, pulse oximetry, 97*t*
Mouth
airway opening technique for, 62
anatomy of, 61*f*, 63–64, 63*f*, 65*f*
anesthesia techniques for, 268, 271–272
salivary glands of, 63
tongue of

during blind intubation, 204
during laryngoscopy, 63
in pediatric airway, 282, 286*t*, 287*f*, 298
Mucosal atomization device (MAD), 271*f*, 272
Mucosal edema, 410
Myopathies
hyperkalemia and, 251, 255
malignant hyperthermia as, 251
succinylcholine and, 255

N

Nasal cannula, 73*t*, 74
Nasal technique, 198
Nasal trumpet. *See* Nasopharyngeal airways
Nasal vasoconstriction, 201, 270
Nasogastric (NG) tube, 283*t*, 290, 293*b*
Nasopharyngeal airways (NPAs), 4, 283*t*, 290, 329
Nasopharyngoscopy, 455
diagnostic, 193
Nasopharynx, 202, 286*t*, 290, 303–304
Nasotracheal intubation. *See also* Blind nasotracheal intubation
anatomy and, 60–68
complications of, 68
contraindications for, 411
perforation during, 60, 62*f*
National Audit Project, fourth, 452
National EMS Scope of Practice Model, 328
National Highway Traffic Safety Administration (NHTSA), 328
Needle cricothyrotomy, 291, 291*t*, 293*b*, 301–303, 304*b*. *See also* Cricothyrotomy
Needle thoracostomy, 450
Negative pressure pulmonary edema, 456*t*
Neostigmine (Prostigmine), 248, 253
Neosynephrine. *See* Phenylephrine
Nephrogenic pulmonary edema, 375
Neurocritical patients, 391–398
challenges, 391
device selection, 396
drugs and dosages, 394*b*
elevated intracranial pressure, 394
ICP response to neuromuscular blockade, 395
induction agent, choice of, 395–396
mechanical ventilation, initiating, 396–397
prolonged seizure activity, 392
reflex sympathetic response to laryngoscopy, 395
RSI and, 393
paralysis with induction, 393
postintubation management, 393–394

preoxygenation, 393
self-limited seizure, 392
status epilepticus, 391
techniques, 392–396
Neuromuscular blocking agents (NMBAs), 227, 234*f*, 235, 237, 242, 358. *See also* specific drugs
advantages of, 254
airway approach to, 434
BMV used after, 44–45
depolarizing, 248
dosage of, 254, 254*t*
glottis visibility influenced by, 64
intubation success rates of, 254
nondepolarizing
adverse effects of, 254
aminosteroid as, 253
benzylisoquinoline as, 253
clinical pharmacology of, 253–254
contraindications for, 254
dosage of, 254, 254*t*
indications for, 254
succinylcholine compared with, 254
onset of, 254*t*
pharmacology of, 253–254
successful attempts and, 259–261
NG tube. *See* Nasogastric (NG) tube
Nimbex. *See* Cisatracurium
NIPPV. *See* Noninvasive Positive Pressure Ventilation
Nitrous oxide, 240
NMBAs. *See* Neuromuscular blocking agents
NMDA. *See* N-methyl-d-aspartate
N-methyl-d-aspartate (NMDA), 241, 242
Noncompetitive NMBAs, 248*t*
Nondepolarizing NMBAs
adverse effects of, 254
aminosteroid as, 253
atropine used with, 253
benzylisoquinoline as, 253
clinical pharmacology of, 253–254
contraindications for, 254
dosage of, 254, 254*t*
indications for, 254
Noninvasive Positive Pressure Ventilation (NIPPV), 85–88, 200, 372, 375, 380, 403, 461
contraindications, 86–87
indications, 86–87
modes of, 86
in obese patient, 441, 444
prehospital airway management and, 337–338
technology of, 85–86

Noninvasive respiratory support, 87
Noninvasive respiratory support, technology for, 85–86
Noninvasive ventilation (NIV), extubation to, 460
Non-rebreather mask, 76
Non-rebreather mask (NRM), 73*t*, 74, 289–290, 293*b*. *See also* Bag-mask ventilation
Non-waveform ETCO2 capnometers, 100, 105
Norcuron. *See* Vecuronium
Normal capnography waveform, 100*f*, 101*f*
Nose. *See also* Nasotracheal intubation
  anatomy of, 60–62, 61*f*, 62*f*
  anesthesia techniques for, 201
  inferior turbinate of, 61*f*, 202
  Kiesselbach's plexus of, 60
  middle turbinate of, 61*f*
  mucosa sensitivity in, 61
  nasotracheal perforation in, 60, 62*f*
  paranasal sinus infections in, 62
  vasoconstriction in, 198, 201, 270

O

Obese patients
  airway approach to, 438–440, 439*b*
  anatomical changes in, 438–440, 439*b*
  anesthesia for, 440
  BMV for, 438, 441, 444
  challenges of, 438
  cricothyrotomies for, 438
  difficult intubation in, 438, 444
  EGDs for, 438, 441
  ILMA and, 441
  oxyhemoglobin desaturation, 444
  positioning of, 440, 441, 444
  postintubation management for, 444
  preoxygenation of, 228, 229*f*, 237, 440, 444
  techniques for, 440–443
  tips for, 443
Obstruction, of upper airway, 193, 275
  airway approach to, 405–409
  awake intubation for, 409
  BMV and, 407
  causes of, 405, 406*b*, 447
  challenges of, 405
  cricothyrotomy for, 405–408
  emergency management of, 409
  by epiglottis, 301
  by foreign body aspiration, 406*b*, 446–451, 448*f*
  in pediatric airway, 282, 285*f*, 297, 301

RSI and, 407
signs of, 405–406
tips for, 408
Obstructive sleep apnea, 431
Occiput, 286*t*, 287*f*, 298, 298*f*, 413
Olanzapine, 234*f*
Operator posture, in direct laryngoscopy (DL), 163
Opioids, 376
in awake intubation sedation, 275
overdose of, 4
pregnancy and, 411
Oral airways, 197, 283*t*, 290, 297
Oral cavity. *See* Mouth
Oral technique, 197
Oropharyngeal identification, 193
Oropharynx, 4, 202, 271–272, 273*f*, 405
Orotracheal intubation
laryngoscopy and, 268
for pediatric airway, 291*t*
Out-of-hospital airway management, 327, 331
Ovassapian guide, 195*f*
Oximeters, 96
Oxygenation. *See also* Preoxygenation
assessment of, 6–7, 40*f*
in bag-mask ventilation (BMV), 322, 323*f*, 408
cricothyrotomy, 408
difficult airway and, 23
EGDs, 408
in emergency medical services (EMS) airway, 328
failure of, 4
maintenance of, 40*f*, 42, 232
Oxygen delivery devices, 74–79
bag-valve mask, 76–79
low-flow and high-flow nasal oxygen, 74–75
non-rebreather mask, 76
Oxygen desaturation during procedural sedation, 103
Oxygen insufflation, 457, 458*t*, 461
Oxygen mask. *See* Bag-mask ventilation
Oxygen saturation, 99
Oxyhemoglobin dissociation curve, 98
Oxymetazoline (Afrin), 201, 270

P

Palatopharyngeal arch, 65*f*, 272
Pancuronium, 254
Paraglossal (retromolar) straight-blade technique, 167, 167*f*
Paralysis, 345

in RSI, 45, 231, 235*t*, 236*t*, 293, 412, 434
Paramedics, 330
Partial airway obstruction, 318, 319
Patient positioning in direct laryngoscopy (DL), 163–165, 166*f*
Patients. *See* Geriatric patients; Obese patients; Trauma patients
Pattern recognition, difficult pediatric airways, 316
Pavulon. *See* Pancuronium
PCV. *See* Pressure cycled ventilation
Peak expiratory flow rate (PEFR), 403
Peak inspiratory pressure (PIP), 90, 402
Pediatric airway. *See also* Difficult pediatric airway
anatomical issues of
adenoids, 286, 286*t*, 303
airway obstruction, 282, 285*f*, 297, 301, 305
anatomical variations, 281, 286, 286*t*
BMV and, 283*t*, 285*f*, 287, 287*b*, 290, 291*t*
cricothyroid membrane, 286, 286*t*, 287*f*, 289*f*, 302, 303, 304*f*
glottic opening, 286, 286*t*, 287*f*, 293*b*
nasopharynx angle, 286*t*, 290, 303–304
noxious interventions and, 282, 285*f*
occiput size, 286*t*, 287*f*, 298, 298*f*, 413
tongue size, 286, 286*t*, 287*f*, 297
trachea, 285*f*, 286, 286*t*, 302
anesthesia for, 251, 287, 288*t*, 294–295
BMV for, 283*t*, 285*f*, 287*b*, 288, 288*t*, 290, 291*t*, 297–301, 298*f*, 302*f*, 303, 304*b*
Broselow-Luten system for, 282, 283*t*–284*t*, 287, 292, 294
challenges in, 281
cognitive burden in managing, 281–282, 294
desaturation and, 237, 287, 287*b*, 293*b*, 295, 297
equipment for, 283*t*–284*t*, 286*t*, 287–291
airway alternatives, 291, 291*t*, 293*b*
BMV, 288*t*, 290, 302, 302*f*
catheters, 283*t*, 302, 302*t*
Combitube, 293*b*
dangerous, 288*t*
ETCO2 detectors, 291
ETTs, 283*t*, 288–289, 288*t*, 289*f*, 302, 302*f*, 303, 304*f*
King LTS-D airway, 303
laryngoscopes, 283*t*, 286*t*, 287–288, 288*t*
nasopharyngeal airways, 283*t*, 290
NG tubes, 290, 293*b*
non-rebreathing masks, 289–290, 293*b*
oral airways, 288*t*, 290
pop-off valves, 291, 300–301
storage of, 288
LMA for, 284*t*, 291, 291*t*, 301
mechanical ventilation initiated in, 291–292, 293*b*
NTI and, 287*f*, 291, 291*t*

optimal alignment of, 298, 298*f*
orotracheal intubation for, 291*t*
physiological issues of, 287, 287*b*, 293*b*
problem, most-feared, 309*t*–310*t*
shape of, 290*f*
sniffing position for, 286*t*, 298, 298*f*
techniques
for adolescents, 303–304, 304*f*
BMV, 297–301, 298*f*, 302*f*, 304*b*
cricothyrotomy, 285*f*, 291, 291*t*, 293*b*, 301–303, 302*t*, 303, 304*b*
ETI, 291, 291*t*
King LTS-D airway contraindicated as, 303
LMA, 301, 304–305
recommendations for, 304*b*
RSI, 293
Seldinger technique, 304*b*
TTJV, 304, 304*b*
Pediatric basic life support (BLS) techniques, 319
Pediatric difficult airway
normal airways and, 307*t*
risk factors, 306*t*
trauma, 312
Pediatric *versus* adult risk factors, 306*t*
PEFR. *See* Peak expiratory flow rate
Penetrating injury, 406
Percutaneous needle tracheostomy (PNT)
versus needle cricothyrotomy, 302
Percutaneous transtracheal ventilation (PTV)
equipment for
transtracheal catheters, 302*t*
for pediatric airway, 304*b*
Peri-intubation complications, 373, 380
Peri-intubation oxygenation, 71–82
concepts, 79–81
apneic oxygenation, 80
apneic period, 80–81
delayed sequence intubation, 79–80
end-tidal oxygen, monitoring using, 79
rescue oxygenation, 81
description of, 71–72
oxygen delivery devices, 74–79
bag-valve mask, 76–79
low-flow and high-flow nasal oxygen, 74–75
non-rebreather mask, 76
simple face mask, 75, 75*f*
venturi masks, 79
principles of, 72–74
high-concentration oxygen delivery *versus* traditional supplemental oxygen, 73–74

positioning, 72–73
preoxygenation with and without positive pressure, 74
Permissive hypercapnia. *See* Hypercapnia
Pharynx, 202
anatomy of, 61*f*, 64, 65*f*
innervation of, 64
Phencyclidine, 242
Phenylephrine (Neo-Synephrine), 201, 231*b*, 270
Physiological reserve, in respiratory, 431
Physiologic optimization, 36, 230–231, 344–345
agents for, 231, 231*b*, 433–434
during RSI, 231*b*, 235, 235*t*, 412, 433–434, 435
in RSI, 231*b*
Physiologic range, in pulse oximetry, 97*t*
Pilot balloon, 151
PIP. *See* Peak inspiratory pressure
Placement with proof, 232, 236*t*, 293, 345, 413
Placenta, 411
Plateau pressure, 402
Pneumothorax, 6, 232*t*, 403, 450
Pop-off valves, 291, 300–301, 303
Positive airway pressure, 89, 285*f*, 400, 441
BiPAP, 400
Positive end-expiratory pressure (PEEP), 74, 90, 92*f*, 375, 400, 402–403, 441
Positive pressure relief valves. *See* Pop-off valves
Positive-pressure ventilation, 5, 85–88, 89, 300–301, 303, 373
Postintubation cardiac arrest, 432
Postintubation hypotension (PIH), 373, 375, 377
Postintubation management, 232–235, 232*t*, 234*f*, 236*t*, 293, 372*b*
for foreign body aspiration, 450
for geriatric patients, 434
for obese patients, 443
pregnancy and, 413
for reactive airways disease, 401–403
Postintubation sedation, cardiopulmonary optimization for emergency airway management, 377, 378*b*–379*b*
Preeclampsia, 411
Pregnancy
airway equipment for, 412, 414
anesthesia during, 412, 414
BMV and, 410, 412
challenges of, 410–411
desaturation during, 229*f*, 411
difficult airway algorithm for, 414
EGDs and, 412
gastrointestinal changes during, 412
hemodynamic stability during, 412
intubation

failed, 413
RSI, 411
mechanical ventilation during, 410
postintubation management and, 413
Sellick maneuver during
surgical airway management during, 412
tips for, 414
Prehospital airway management, techniques in, 334–349
location/environmental factors, 334
medication-facilitated airway management, 343–347
paralysis with induction, 345
physiologic optimization, 344–345
placement with proof, 345
positioning, 345
post-intubation management, 345–348
preoxygenation, 344
preparation, 344
monitoring, patient, 337
oxygen consumption/tank factors, 348–349
positioning, patient, 334–336, 335*f*–336*f*
procedures, verification of, 343
skills in, 337–341
bag-mask ventilation, 337
endotracheal intubation, 338–341
noninvasive positive pressure ventilation, 337–338
transport considerations, 348
package, 348
positioning, 348
video laryngoscopy, 341–342
Prehospital setting, 356
blind nasotracheal intubation (BNTI), 205
challenge, 352
conundrum, 353
emergency medical services (EMS) airway, 327–332
human factors in, 330–331
prediction of difficult airway in, 352–353
Preintubation optimization, 228
of patient’s airway, 163
during RSI, 236*t*
Preoxygenation, 72–74, 344, 371*b*, 378*b*–379*b*, 380
airway approach to, 433
considerations in unstable patients, 374–375
desaturation during
in children, 228, 229*f*, 237, 287, 287*b*, 293*b*, 295, 297
in obese patients, 228, 229*f*, 237, 441, 444
in pregnant women, 228, 229*f*, 412
time to, 228–230, 229*f*
high-concentration oxygen *versus* supplemental oxygen, 73–74

nasal cannula, 74
non-rebreather mask, 76
in NTI, 201
optimal method for, 237
principles of, 72–74
high-concentration oxygen delivery *versus* traditional supplemental oxygen, 73–74
positioning, 72–73
with and without positive pressure, 74
in RSI, 228–230, 229*f*, 235, 235*t*, 236*t*, 237, 238, 293, 412
successful attempts and, 262–263
variables for, difficult airway and, 24*b*
Pressure-control ventilation (PCV), 91, 92–93, 92*f*–93*f*
Pressure cycled ventilation (PCV), 292*t*
Pressure-limited ventilators, 292*t*
Pressure support ventilation (PSV), 91
Procedural sedation, ventilation monitoring, 103–104
Progesterone, 410
Propofol (Diprivan), 233, 377
adverse effects of, 244
in awake intubation sedation, 275
clinical pharmacology of, 243
contraindications for, 243
dosage of, 243, 443*t*
indications for, 243
as induction agent, 233, 240, 243–244, 246, 434
ketamine used with, 275
lidocaine used with, 244
for obese patients, 443*t*
for pediatric airway, 288*t*
reactive airways disease and, 401, 402
for RSI, 245–246
ProSeal LMA (PLMA), 414
Prostigmin. *See* Neostigmine
Pseudocholinesterase (PCHE), 249, 252
PSV. *See* Pressure support ventilation
Psychomotor airway skills, 330
PTV. *See* Percutaneous transtracheal ventilation
Pulmonary aspiration, 456*t*
Pulmonary embolism, in ETCO2, 104
Pulse oximetry, 7, 230
during emergency airway management, 104
indication, 96–97
limitations and precautions, 97–98, 97*t*
measurement principles, 96
physiologic insight and limitations, 98–99
response time, 98
signal reliability, 97–98
Pyridostigmine, 248

Q

Quantitative CO2 monitors, 100–101, 100*f*
Quetiapine, 234*f*

R

Rapid Fit connectors, 457*f*
Rapid Oral Tracheal Intubation Guidance System (ROTIGS) airway, 195, 195*f*
Rapid sequence airway (RSA), 328
  successful attempts and, 259–260
Rapid sequence intubation (RSI), 373
  adverse events in, 236
  airway obstruction and, 405, 408
  benzodiazepines, 246
  blind intubation techniques and, 200
  contraindications for, 227
  in difficult airways, 44–45
  double setup for, 45
  and drug use, 371*b*
  for emergency airway management, 71
  etomidate, 245
  example of, 236, 236*t*
  for geriatric patients, 432–433
  hemodynamic consequences of, 238
  indications for, 38*f*–39*f*, 41, 200, 205, 227, 269
  induction agents in, 245–246
  ketamine, 245
  ketofol, 245
  neurocritical patients and
    paralysis with induction, 393
    postintubation management, 393–394
    preoxygenation, 393
  paralysis, 434
  for pediatric airway, 293, 312, 317
  physiologic optimization for, 433–434
  positioning in, 235*t*, 236*t*, 293, 413, 440, 441, 441*f*
  postintubation management, 434
  preparation for, 228, 235*t*, 236*t*, 293, 412
  propofol, 245
  reactive airways disease and, 401, 403, 404
  sedation and, 233, 238
  Sellick’s maneuver during, 227, 293
  steps of, 3, 228*b*, 235*t*, 236*t*
    paralysis, 231, 235*t*, 236*t*, 293, 412
    physiologic optimization, 412
    placement with proof, 232, 235*t*, 236*t*, 293, 413
    positioning, 231–232, 235*t*, 236*t*, 293, 413, 441, 444
    postintubation management, 232–235, 232*t*, 234*f*, 235*t*, 236*t*, 293, 401–403, 413, 443

preintubation optimization, 235*t*, 236*t*, 293
preoxygenation, 228–230, 229*f*, 235, 235*t*, 236*t*, 237, 293, 412
preparation, 228, 235*t*, 236*t*, 293, 412
success of, 45, 236
succinylcholine, 434, 435
timing of, 235
Reactive airways disease. *See also* Asthma; Chronic obstructive pulmonary disease
barotrauma with, 402
catecholamines and, 404
challenges of, 400–401
desaturation with, 401
in geriatric patients, 434
hemodynamic stability and, 400
hypotension with, 402
mechanical ventilation for, 402
postintubation management for, 401–403
RSI and, 403
technique for, 401
treatment of, 400, 401–403
Receptor upregulation, 251
Recruitment maneuvers (RMs), 444
Reflectance oximeters, 98
Reflex sympathetic response to laryngoscopy (RSRL), 395
cardiorespiratory emergencies and, 417–418
Reintubation, airway exchange catheter (AEC) for, 458*t*, 459, 459*t*, 461
Remifentanil, 275
Rescue oxygenation, 81
Respiratory compromise, 372–373
Respiratory depression, 103
patients assessment and monitoring in, 104
Respiratory rate (RR), 89–90
Respiratory support, noninvasive, 85–86
Respiratory therapist (RT), 94
Restricted neck movement, 313
Resuscitation, 375
Retroglottic devices (RGD), 125–128
esophageal tracheal combitube, 126
insertion techniques, 127–128
laryngeal tube airway, 127
Rusch EasyTube, 126–127
Retroglottic devices (RGDs)
ETC. *See* Combitube
Return of spontaneous circulation (ROSC), 102
Reversible conditions, intubation and, 4
RGDs. *See* Retroglottic devices
Rhabdomyolysis, 251
Richmond Agitation Sedation Scale, 233, 233*b*
Right ventricular failure, 378*b*

Rigid bronchoscopy, 308
Robinul. *See* Glycopyrrolate
Rocuronium, 232, 246, 249, 254–255, 254*t*
  dosage of, 254, 436, 443*t*
  for geriatric patients, 434
  for obese patients, 443*t*
  for pediatric airway, 288*t*, 293, 294
  pregnancy and, 411, 412
  sugammadex reversing, 256
RODS mnemonics, 16, 40, 412
ROMAN mnemonics, 40, 411, 412
ROSC. *See* Return of spontaneous circulation
ROTIGS airway, 195, 195*f*
RR. *See* Respiratory rate
RSI. *See* Rapid sequence intubation
RSRL. *See* Reflex sympathetic response to laryngoscopy
RT. *See* Respiratory therapist
three3-3-2 rule, 192
Rusch EasyTube, 126–127
Rushed/frantic laryngoscopy, 173*t*

S

Safe apnea time, 71
SALAD Technique, 426–428
Salicylate toxicity, 373
Salivary glands, 63
SCh. *See* Succinylcholine
Sedation. *See also* Induction agents
  for awake intubation, 243, 269, 274–275
  contraindications for, 269
  description of, 269
  during extubation, 460
  indications for, 269
  induction drugs, 376
  ketamine, 319
  procedural, ventilation monitoring, 103–104
  Richmond Agitation Sedation Scale for, 233, 233*b*
  RSI and, 233, 238
  techniques for, 269
Seldinger technique, 213–219
  for cricothyrotome, 304*b*
  for pediatric airway, 304*b*
Sellick maneuver, 227, 293, 297
Semielective exchange, for ETT
  blind exchange, 145–146
  consideration of, 144
  endoscopic exchange, 147–150, 150*f*, 151*f*

performance of, 144–150
removal after intubation, 150–152
removal with routine intubation via direct/video laryngoscopy, 144–145
surgical airway, 152
techniques, 145*t*
working around device and performing intubation with direct/video laryngoscopy, 145
Sensor location, pulse oximetry, 97*t*
Sepsis, 373
decreased systemic vascular resistance in, 375
etomidate and, 245
ketamine and, 245
shock, 378*b*
Severe infections, 251
Severe metabolic academia (MA), 379*b*
SGDs. *See* Supraglottic devices
Shock, 5, 245
Shock index (SI), 375
Signal degradation, pulse oximetry, 97*t*
Signal reliability, pulse oximetry, 97–98
Simple face mask, 75, 75*f*
SIMV. *See* Synchronized intermittent mandatory ventilation
SMART mnemonics, 16–17, 40
for difficult cricothyrotomy, 207*b*
Sniffing position, 163, 164*f*, 175, 202, 286*t*, 298, 298*f*
Sodium bicarbonate, 252
Spine injury. *See* Cervical spine injury
Spontaneous mode, 86
Standard direct laryngoscopy technique, 160*f*, 165–166, 165*f*, 166*f*
Standard geometry video laryngoscopy, 182–185
Status asthmaticus, 4
Status epilepticus, 391
Stridor, 6*b*, 7–7, 295, 406
Stylets, 168*f*
pediatric, 283*t*
usage of, 205, 228
Subdiaphragmatic abdominal thrusts, 319
Sublimaze. *See* Fentanyl
Succinylcholine (SCh), 228, 248–249, 311, 457*t*
ACH molecules composing, 249
adverse effects of
bradycardia, 249, 252
fasciculations, 250
hyperkalemia, 249, 256, 287
malignant hyperthermia, 252–253
prolonged neuromuscular blockade, 252
trismus/masseter muscle spasm, 253
atropine used with, 249
clinical pharmacology of, 249

contraindications for, 249, 412
degradation of, 252
denervation and, 255
dosage, 249–250, 254*t*, 436, 443, 443*t*
for geriatric patients, 434
indications, 249
myopathies and, 251, 255
NMBAs and, 253, 254, 254*t*
for obese patients, 442, 443*t*
for pediatric airway, 251, 287, 288*t*, 294
pregnancy and, 411
reactive airways disease and, 401
Succinylmonocholine, 249
Sugammadex, 249, 254, 256
Superior laryngeal nerve, 66*f*, 273
Supraglottic devices, 128–132
laryngeal mask airways, 128–130
Ambu LMA, 131
Cookgas Air-Q, 131
Intersurgical i-gel, 132
techniques for usage of, 132–135
Supraglottic devices (SGDs). *See* Laryngeal mask airway
Supraglottic foreign body, identification of, 319
Supraglottitis. *See* Epiglottitis
Surgical airway management. *See also* Cricothyrotomy; Percutaneous transtracheal ventilation
emergency, 206–221. *See also* Emergency surgical airways
during pregnancy, 412
SVR. *See* Systemic vascular resistance
Swallowing, 4
Sympathetic stimulation, of larynx, 64
Synchronized intermittent mandatory ventilation (SIMV), 91
Systemic vascular resistance (SVR), 244
Systolic blood pressure (SBP), 374

T

Tactile digital intubation. *See* Digital tracheal intubation
TBI. *See* Traumatic brain injury
Tenaculum, 448
Tension pneumothorax, 232
Terbutaline, 400
Tetracaine, 270
Thoracostomy, needle, 450
Thoracostomy tube, 231*b*
Thyrohyoid membrane, 274
Thyroid cartilage, during laryngoscopy, 175
Thyroid pressure. *See* Backward, Upward, Rightward Pressure (BURP) maneuver
Tidal volume (TV), 89, 291, 402

Tissue edema, 374
Tongue
during blind intubation, 204
during laryngoscopy, 63
in pediatric airway, 286*t*, 287*f*, 297
Tonsils, 286, 286*t*
suction, 197
Topicalization, 459, 460
Total body weight (TBW) dosing, 443
Towel clip, 448
Trachea
anatomy of, 61*f*, 66*f*, 67, 285*f*
anesthesia techniques for, 274
examination of, 6
extrathoracic, 282, 285*f*
intrathoracic, 285*f*
intubation confirmed in, 204
in pediatric airway, 282, 285*f*, 286, 286*t*, 302
Tracheal intubation, 193
confirmation, 173–174
in direct laryngoscopy, 161, 166, 169*f*, 170
endotracheal tube (ETT) in, 161, 169*f*
Tracheostomy
awake, 276
Transmission oximetry, 96
Transtracheal catheters, 302*t*
Transtracheal jet ventilation. *See* Percutaneous transtracheal ventilation
Trauma patients. *See also* Difficult airway
pediatric difficult airway in, 312
Traumatic airway, 382–390
approaches, 382–387
ABCs of, 384–388, 384*t*
difficulty, assessment of, 383
special considerations, 383–388, 384*t*
challenges, 382
failed airway, 389
techniques, 388, 389*t*
induction agent, choice of, 388
neuromuscular blocking agent, choice of, 388
paralysis *versus* rapid tranquilization, 388
RSI, 388
Traumatic brain injury (TBI), 245
Trismus/masseter muscle spasm, 253
Tubarine. *See* D-tubocurarine
TV. *See* Tidal volume

U

Ultrasound, in obese patient, 444
Uncompensated shock, 374, 377
Unexpected pediatric difficult airway therapeutic options, 307*t*
Universal emergency airway algorithm, 37, 38*f*
Unstable patients
  clinical challenge, 371
  optimization for first laryngoscopy attempt success, 371–377, 372*b*
    hemodynamic optimization, 375–376
    induction, 376
    mechanical ventilation, 376–377
    postintubation sedation, 377
    preoxygenation considerations, 374–375
    timing of airway management, 372–374
Upper airway. *See also* Obstruction, of upper airway
  anatomy of, 60–67, 61*f*, 405–406
  distortion of, 5, 405–409, 411
  larynx of, 6, 61*f*, 64–67, 65*f*–66*f*, 202, 205, 273–274, 286*t*, 304*f*, 408
  mouth of, 61*f*, 63–64, 63*f*, 65*f*, 268, 271–272
  nose of, 60–62, 61*f*, 62*f*, 201–202, 270
  obstruction, 6*b*, 454, 456*t*
  pharynx in, 61*f*, 64, 65*f*, 202
  tongue of, 63, 205, 286, 286*t*, 287*f*, 297
  trachea of, 6, 61*f*, 66*f*, 67, 204, 274, 282, 285*f*, 286, 286*t*, 302

V

Vagus nerve, 66*f*
Valium. *See* Diazepam
Vascular engorgement, 411
Vasoconstriction
  anesthesia with, 270
  epinephrine causing, 282
  nasal, 198, 201, 270
Vasodilated shock, 373
Vasopressors, 373, 374, 375
VC ventilation. *See* Volume cycled ventilation
Vecuronium, 234*f*, 253–254
  dosage of, 443*t*
  for obese patients, 443*t*
  for pediatric airway, 288*t*
  pregnancy and, 411
Ventilation
  assist control (AC), 91
  bag-mask ventilation (BMV). *See* Bag-mask ventilation (BMV)
  in emergency medical services (EMS) airway, 328
  failure of, 4
  foreign body aspiration and, 448–449, 448*f*
  maintenance of, 43, 44–45

mechanically ventilated patients. *See* Mechanical ventilation
monitoring during procedural sedation, 103–104
synchronized intermittent mandatory ventilation (SIMV), 91
Ventilation-perfusion (V/Q) mismatches, 439, 439*b*
Ventilator-induced lung injury (VILI), 95
Ventilators
pressure-limited, 292*t*
VILI from, 95
volume-limited, 292*t*
Ventolin. *See* Albuterol
Venturi mask, 73*t*, 79
Versed. *See* Midazolam
Video laryngoscopy (VL), 3, 36, 40, 40*f*, 41*f*, 178–190, 228, 407, 408, 455, 460
advantages of, 179
classification of, 179–181
complications of, 188
description of, 178
difficult pediatric airway, 312
direct laryngoscopy *vs*., 182
hyperangulated, 185–188
prehospital airway management and, 341–342
routine intubation, 144–145
standard geometry, 182–185
working around EGD, 145, 146*f*
Visualization
of epiglottis, 286, 407
foreign body, 322
of glottis, 45, 64, 161, 167–168, 169–170, 172*f*, 202, 268–269, 299, 459
of larynx, 205, 286*t*, 408
Vocal cords, 159, 164*f*, 166, 175, 204, 285*f*, 456*t*
Volume-control ventilation (VCV), 91, 92*f*
flow characteristics, 91
waveform, 92*f*
Volume cycled ventilation (VCV), 292*t*
Volume-limited ventilators, 292*t*
V/Q mismatches. *See* Ventilation-perfusion (V/Q) mismatches

W

Waveform capnography, 100*f*, 142, 142*f*
CO2 monitoring, 100–101
Wheezing, in children, 318
Williams airway, 195*f*
WOB. *See* Work of breathing
Work of breathing (WOB), 91

X

Xenon, 240
Xylocaine. *See* Lidocaine

Z

Zero Point Survey, 54, 55*f*

The 'Gold Standard' in Airway Management Education

the difficult airway course™ EMERGENCY

This 2½ day immersion in emergency airway management will advance the skills of even the most experienced providers. Taught by a world-class faculty of airway experts, this evidence-based course sets the standard for airway education.

the difficult airway course™ ANESTHESIA

This intensive 2½ day course features advanced, hands-on education in difficult airway & awake intubation, failed airway & open cricothyrotomy, safe extubation & airway exchange catheter, and crisis team leadership. Even the most experienced anesthesia providers will take their airway practice to the next level with this course.

the difficult airway course™ CRITICAL CARE

This 2½ day immersion in difficult airway management is specifically designed for providers facing airway challenges posed by critically ill inpatients.

the difficult airway course™ RESIDENCY EDITION

A milestone and evidence-based airway curriculum designed to be incorporated into your existing Resident education program. Teach this curriculum yourself as a Program Member or host our faculty to teach a one-day course.

the difficult airway course™ CUSTOM PROGRAM

Custom designed programs to provide a highly focused training experience tailored to your specific educational goals. One-day, two-day or partial-day programs available.

the difficult airway course™ EMS

This intensive, two-day immersion program in EMS airway management will provide you with the knowledge and skills you need to confidently manage any airway situation.

essentials of advanced airway management™

Designed for Advanced EMS providers whose protocols do not include medication-facilitated airway management. Learn to optimize the airway without using medication in this one-day course.

fundamentals of airway management™

A one-day course for Basic and Intermediate EMS providers. Empower yourself by mastering the most important foundational airway skills.

For Course Dates, Locations and Registration Information, visit theairwaysite.com.